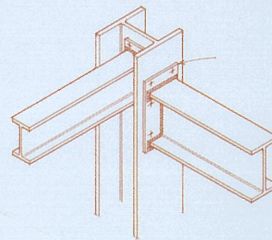


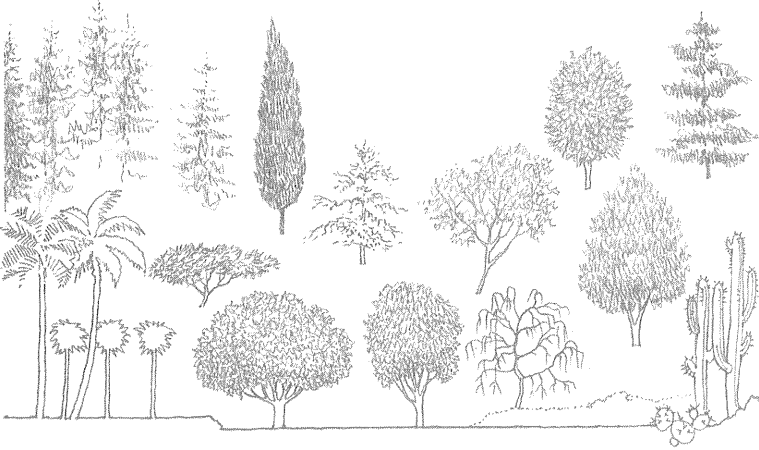
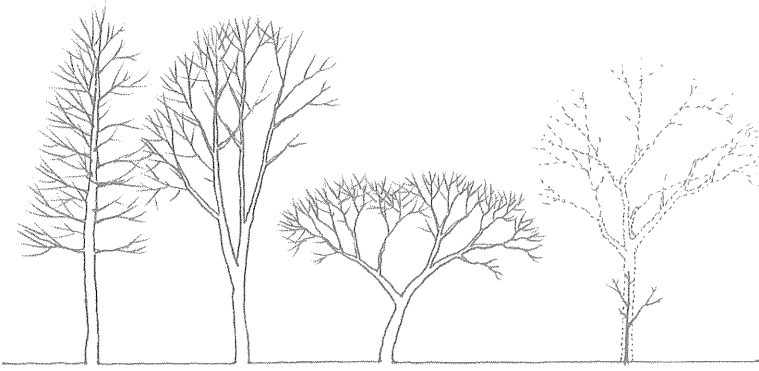


building construction illustrated

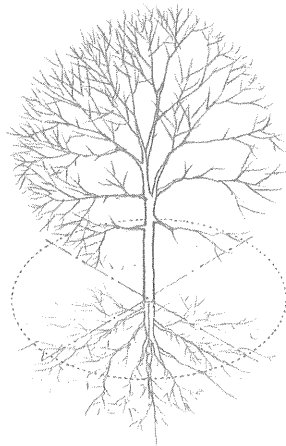
FOURTH EDITION



FRANCIS D.K. CHING



LEED SS Credit 6: Minimize Impervious Surfaces
 LEED SS Credit 7: Reduce Heat Island Effect
 LEED WE Credit 1: Water Efficient Landscaping



Plant materials provide aesthetic as well as functional benefits in conserving energy, framing or screening views, moderating noise, retarding erosion, and visually connecting a building to its site. Factors to consider in the selection and use of plant materials in landscaping include the:

- Tree structure and shape
- Seasonal density, texture, and color of foliage
- Speed or rate of growth
- Mature height and spread of foliage
- Requirements for soil, water, sunlight, and temperature range
- Depth and extent of the root structure

• Trees and other plant life adapt their forms to the climate.

- Existing healthy trees and native plant materials should be preserved whenever possible. During construction and when regrading a site, existing trees should be protected for an area equal to the diameter of their crowns. The root systems of trees planted too close to a building may disturb the foundation system. Root structures can also interfere with underground utility lines.
- To support plant life, a soil must be able to absorb moisture, supply the appropriate nutrients, be capable of aeration, and be free of concentrated salts.

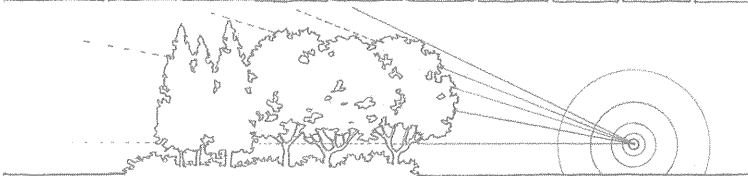
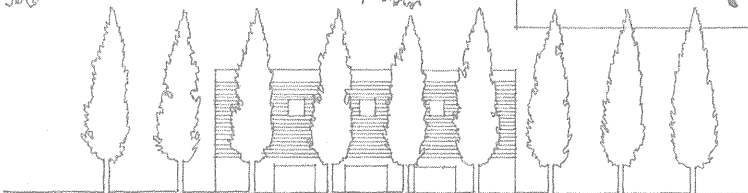
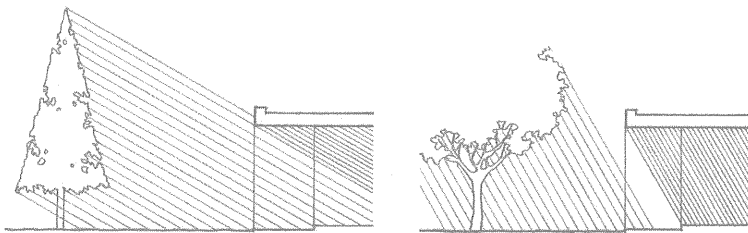
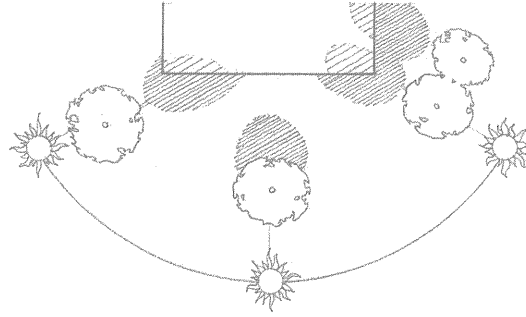
Grass and other ground covers:

- Can reduce air temperature by absorbing solar radiation and encouraging cooling by evaporation;
- Aid in stabilizing soil embankments and preventing erosion;
- Increase the permeability of soil to air and water.

• Vines can reduce the heat transmission through a sunlit wall by providing shade and cooling the immediate environment by evaporation.



Trees affect the immediate environment of a building in the following ways:



Providing Shade

The amount of solar radiation obstructed or filtered by a tree depends on its:

- Orientation to the sun
 - Proximity to a building or outdoor space
 - Shape, spread, and height
 - Density of foliage and branch structure
- Trees shade a building or outdoor space most effectively from the southeast during the morning and the southwest during the late afternoon when the sun has a low altitude and casts long shadows.
 - South-facing overhangs provide more efficient shading during the midday period when the sun is high and casts short shadows.
 - Deciduous trees provide shade and glare protection during the summer and allow solar radiation to penetrate through their branch structures during the winter.
 - Evergreens provide shade throughout the year and help reduce snow glare during the winter.

Serving as Windbreak

- Evergreens can form effective windbreaks and reduce heat loss from a building during the winter.
- The foliage of plant materials reduces wind-blown dust.
- See also 1.24.

Defining Space

- Trees can shape outdoor spaces for activity and movement.

Directing or Screening Views

- Trees can frame desirable views.
- Trees can screen undesirable views and provide privacy for outdoor spaces.

Attenuating Sound

- A combination of deciduous and evergreen trees is most effective in intercepting and attenuating airborne sound, especially when combined with earth mounds.

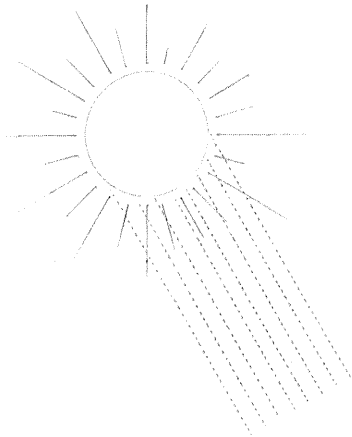
Improving Air Quality

- Trees trap particulate matter on their leaves, which is then washed to the ground during rainfall.
- Leaves can also assimilate gaseous and other pollutants.
- Photosynthetic process can metabolize fumes and other odors.

Stabilizing Soil

- The root structures of trees aid in stabilizing soil, increasing the permeability of the soil to water and air, and preventing erosion.

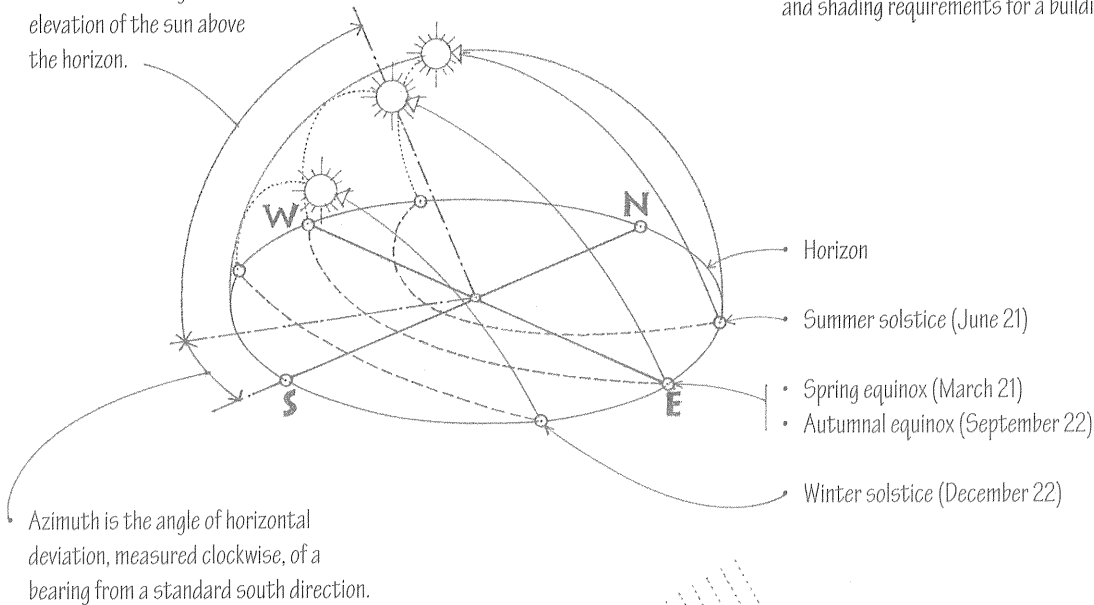
1.14 SOLAR RADIATION



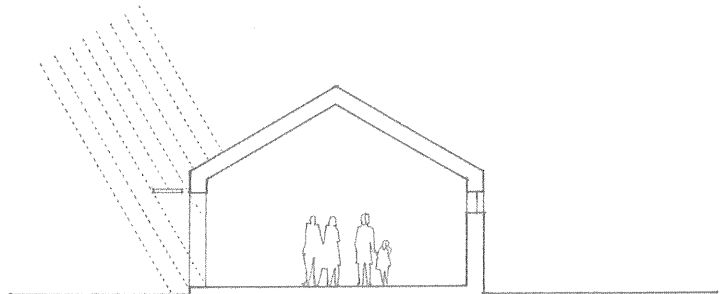
The location, form, and orientation of a building and its spaces should take advantage of the thermal, hygienic, and psychological benefits of sunlight. Solar radiation, however, may not always be beneficial, depending on the latitude and climate of the site. In planning the design of a building, the objective should be to maintain a balance between overheated periods when solar radiation is beneficial and overheated periods when radiation should be avoided.

The path of the sun through the sky varies with the seasons and the latitude of a building site. The range of solar angles for a specific site should be obtained from a weather almanac or service bureau before calculating the potential solar heat gain and shading requirements for a building design.

• Altitude is the angular elevation of the sun above the horizon.



Solar Path Diagram



Representative Solar Angles

North Latitude	Representative City	Altitude at Noon		Azimuth at Sunrise & Sunset*	
		Dec. 22	Mar. 21/Sept. 22	Dec. 22	June 21
48°	Seattle	18°	42°	54°	124°
44°	Toronto	22°	46°	56°	122°
40°	Denver	26°	50°	58°	120°
36°	Tulsa	30°	54°	60°	118°
32°	Phoenix	34°	58°	62°	116°

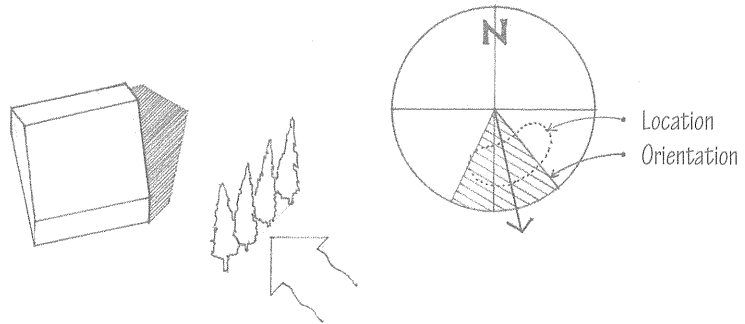
* Azimuth is east of south for sunrise, and west of south for sunset.

The following are recommended forms and orientations for isolated buildings in different climatic regions. The information presented should be considered along with other contextual and programmatic requirements.

Cool Regions

Minimizing the surface area of a building reduces exposure to low temperatures.

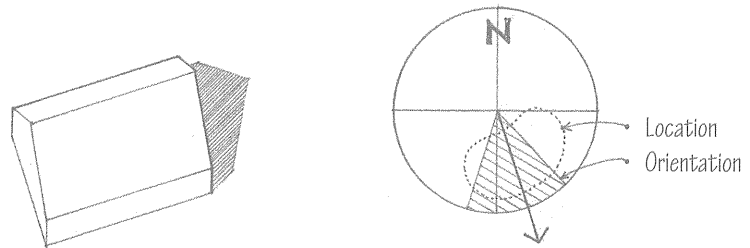
- Maximize absorption of solar radiation.
- Reduce radiant, conductive, and evaporative heat loss.
- Provide wind protection.



Temperate Regions

Elongating the form of a building along the east-west axis maximizes south-facing walls.

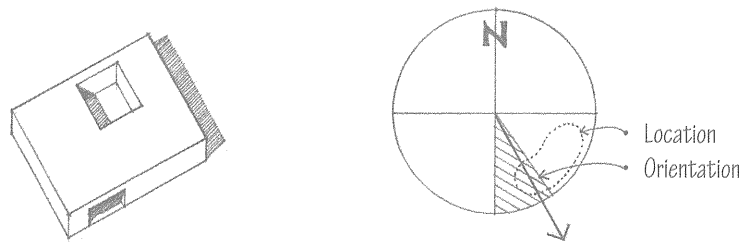
- Minimize east and west exposures, which are generally warmer in summer and cooler in winter than southern exposures.
- Balance solar heat gain with shade protection on a seasonal basis.
- Encourage air movement in hot weather; protect against wind in cold weather.



Hot-Arid Regions

Building forms should enclose courtyard spaces.

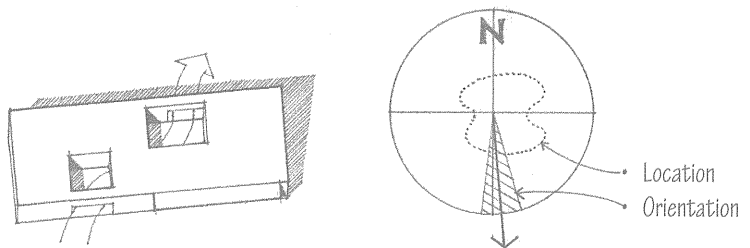
- Reduce solar and conductive heat gain.
- Promote cooling by evaporation using water features and plantings.
- Provide solar shading for windows and outdoor spaces.



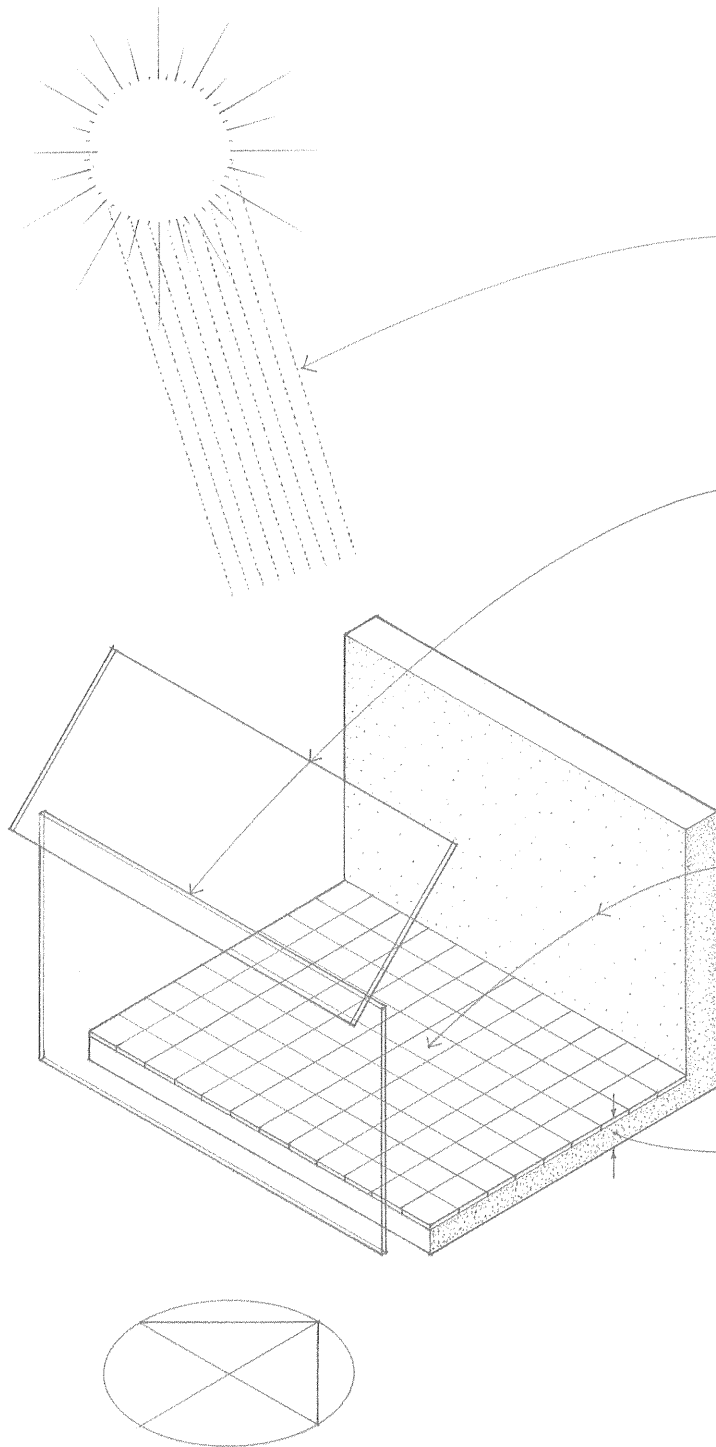
Hot-Humid Regions

Building form elongated along the east-west axis minimizes east and west exposures.

- Reduce solar heat gain.
- Utilize wind to promote cooling by evaporation.
- Provide solar shading for windows and outdoor spaces.



1.16 PASSIVE SOLAR DESIGN



Passive solar heating refers to using solar energy to heat the interior spaces of a building without relying on mechanical devices that require additional energy. Passive solar systems rely instead on the natural heat transfer processes of conduction, convection, and radiation for the collection, storage, distribution, and control of solar energy.

The solar constant is the average rate at which radiant energy from the sun is received by the earth, equal to 430 Btu per square foot per hour (1353 W/m²/hr), used in calculating the effects of solar radiation on buildings.

There are two essential elements in every passive solar system:

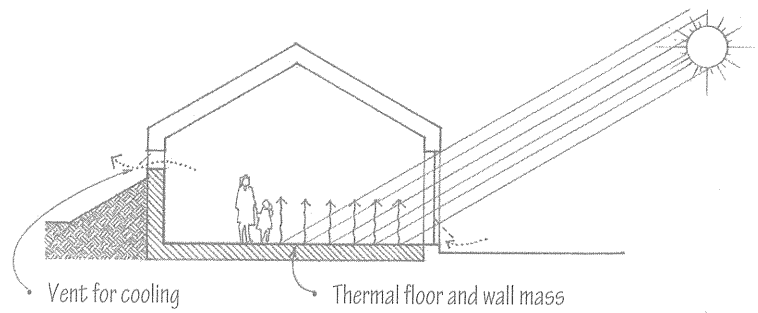
1. South-facing glass or transparent plastic for solar collection
 - Area of glazing should be 30% to 50% of floor area in cold climates and 15% to 25% of floor area in temperate climates, depending on average outdoor winter temperature and projected heat loss.
 - Glazing material should be resistant to the degradation caused by the ultraviolet rays of the sun.
 - Double-glazing and insulation are required to minimize nighttime heat loss.
 2. A thermal mass for heat collection, storage, and distribution, oriented to receive maximum solar exposure
 - Thermal storage materials include concrete, brick, stone, tile, rammed earth, sand, and water or other liquid. Phase-change materials, such as eutetic salts and paraffins, are also feasible.
 - Concrete: 12" to 18" (305 to 455)
 - Brick: 10" to 14" (255 to 355)
 - Adobe: 8" to 12" (200 to 305)
 - Water: 6" (150) or more
 - Dark-colored surfaces absorb more solar radiation than light-colored surfaces.
- Vents, dampers, movable insulation panels, and shading devices can assist in balancing heat distribution.

Based on the relationship between the sun, the interior space, and the heat collection system, there are three ways in which passive solar heating can be accomplished: direct gain, indirect gain, and isolated gain.

LEED EA Credit 2: On-Site Renewable Energy
LEED EA Credit 6 Green Power

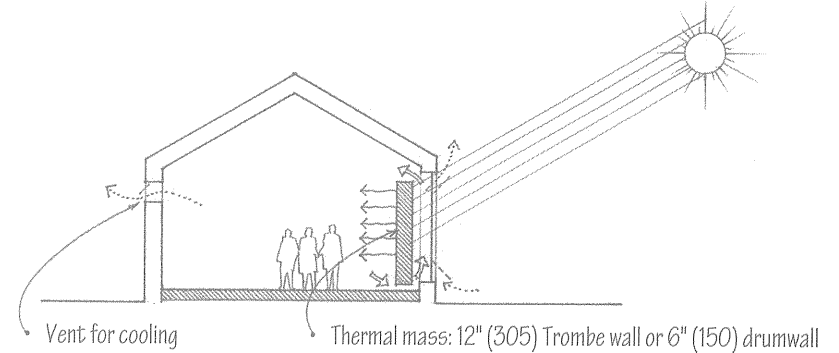
Direct Gain

Direct gain systems collect heat directly within an interior space. The surface area of the storage mass, which is incorporated into the space, should be 50% to 66% of the total surface area of the space. During the cooling season, operable windows and walls are used for natural or induced ventilation.



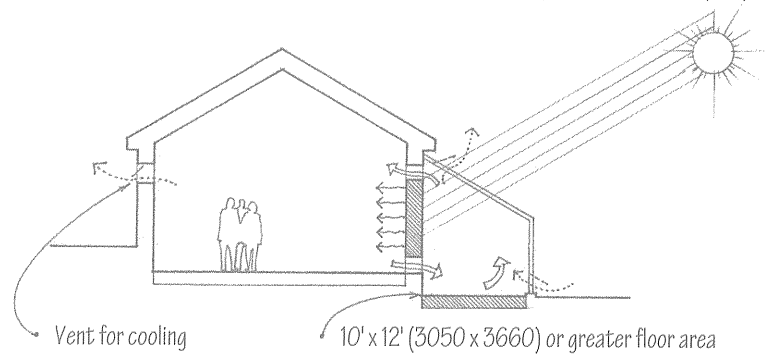
Indirect Gain

Indirect gain systems control heat gain at the exterior skin of a building. The solar radiation first strikes the thermal mass, either a concrete or masonry Trombe wall, or a drumwall of water-filled barrels or tubes, which is located between the sun and the living space. The absorbed solar energy moves through the wall by conduction and then to the space by radiation and convection.



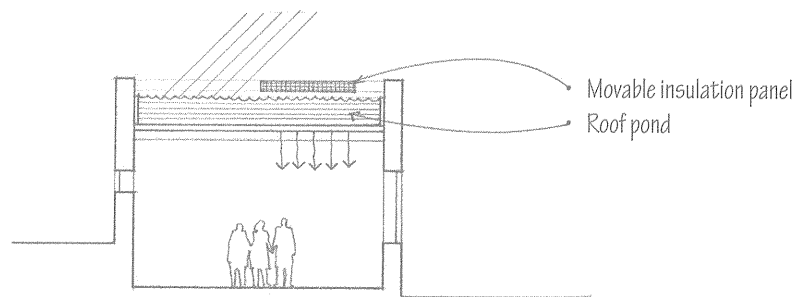
Sunspace

A sunroom or solarium is another medium for indirect heat gain. The sunspace, having a floor of high thermal mass, is separated from the main living space by a thermal storage wall from which heat is drawn as needed. For cooling, the sunspace can be vented to the exterior.



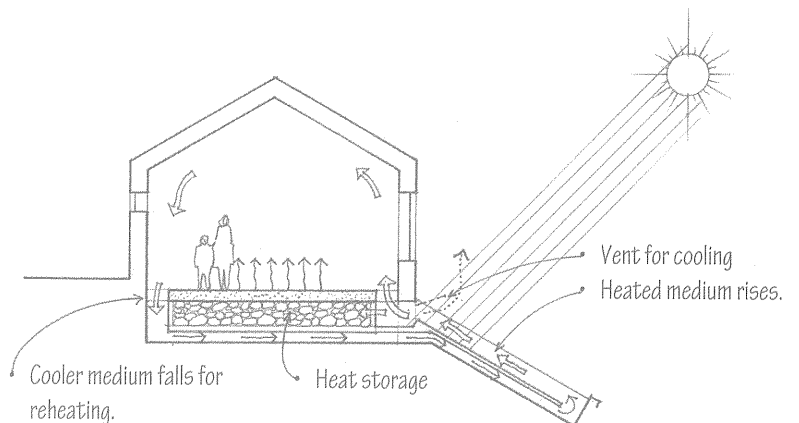
Roof Pond

Another form of indirect gain is a roof pond that serves as a liquid mass for absorbing and storing solar energy. An insulating panel is moved over the roof pond at night, allowing the stored heat to radiate downward into the space. In summer, the process is reversed to allow internal heat absorbed during the day to radiate to the sky at night.

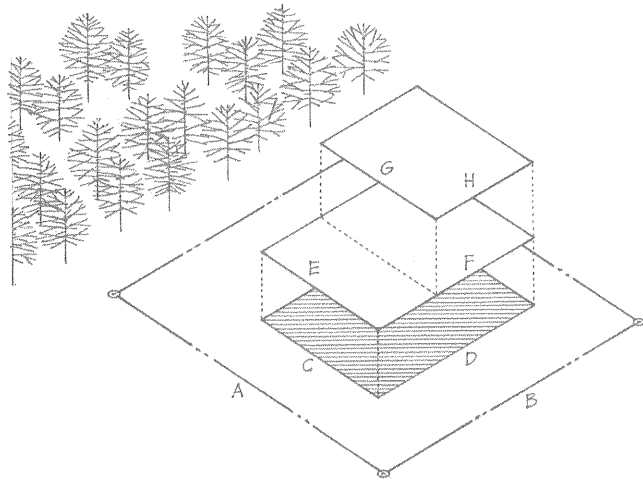


Isolated Gain

Isolated gain systems collect and store solar radiation away from the space to be heated. As air or water in a collector is warmed by the sun, it rises to the served space or is stored in the thermal mass until needed. Simultaneously, cooler air or water is pulled from the bottom of the thermal storage, creating a natural convection loop.



1.24 REGULATORY FACTORS



- Percentage of allowable lot coverage = $(C \times D) / (A \times B)$
- Percentage of allowable total floor area = $[(C \times D) + (E \times F) + (G \times H)] / (A \times B)$

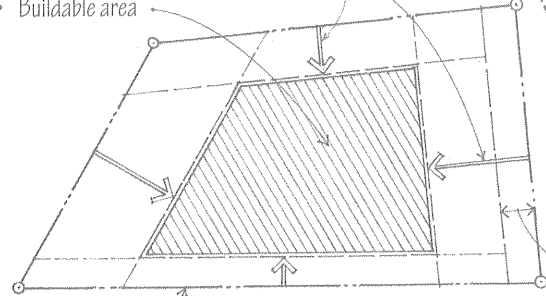
Zoning ordinances are enacted within a municipality or land-use district to manage growth, regulate land-use patterns, control building density, direct development to areas with adequate services and amenities, protect environmentally sensitive areas, and conserve open space.

For any single building site, a zoning ordinance will regulate both the types of activity that may occur on it and the location and bulk of the building or buildings constructed to house such activities. A special type of zoning ordinance is the Planned Unit Development, which allows a fairly large tract of land to be developed as a single entity for added flexibility in the placement, grouping, size, and use of structures.

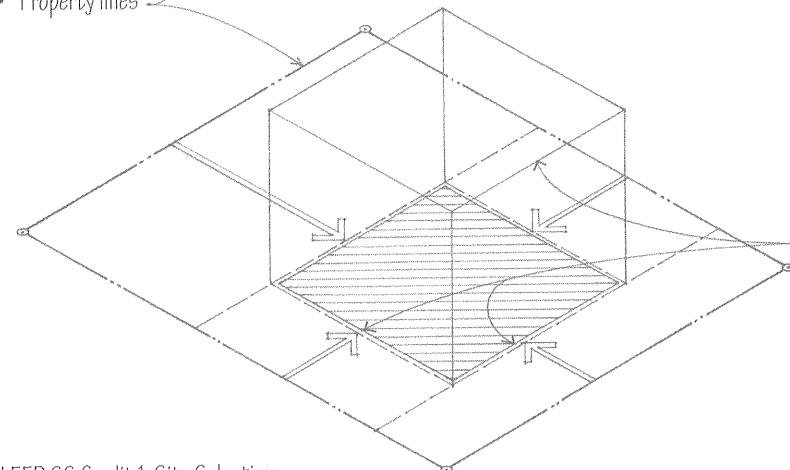
It is important to understand how a zoning ordinance might constrain the allowable size and shape of a building. The bulk of a building is regulated directly by specifying various aspects of its size.

- Percentage of allowable width or depth = C/A or D/B

- Required front, side, rear setbacks
- Buildable area



- Property lines



- How much of the land can be covered by a building structure and the total floor area that may be constructed are expressed as percentages of the lot area.
- The maximum width and depth a building may have are expressed as percentages of the dimensions of the site.
- Zoning ordinances also specify how tall the building structure can be.

The size and shape of a building are also controlled indirectly by specifying the minimum required distances from the structure to the property lines of the site in order to provide for air, light, solar access, and privacy.

Existing easements and rights-of-way may further limit the buildable area of a site.

- An easement is a legal right held by one party to make limited use of the land of another, as for a right-of-way or for access to light and air.
- A right-of-way is a legal right granted to a single party or the public to traverse another's land, as for access or the construction and maintenance of utility lines.

All of the above requirements, together with any restriction on type and density of use, define a three-dimensional envelope beyond which the volume of a building may not extend. Refer to the applicable zoning ordinance for specific requirements.

Exclusions to the general requirements of a zoning ordinance may exist in the form of exceptions or allowances. Exceptions to the normal setback requirements may be made for:

- Projections of architectural features such as roof overhangs, cornices, bay windows, and balconies
- Accessory structures such as low-level decks, fences, and detached carports or garages
- Precedents set by existing, neighboring structures

Exceptions are often made for sloping sites, or for sites adjacent to public open spaces.

- Sloping roofs, chimneys, and other roof projections may be allowed to extend beyond the normal height limitation.
- The height limit may be directly related to the slope of a site.
- A reduction in the setback requirements may be made for sloping sites or for sites fronting on open space.

In order to provide for adequate light, air, and space, and to enhance the streetscape and pedestrian environment, requirements may exist for:

- Open spaces accessible to the public (LEED SS Credit 5: Site Development: Maximize Open Space)
- Additional setbacks if a structure rises above a certain height
- Modulation of the facade of a building fronting a public space
- Vehicular access and off-street parking

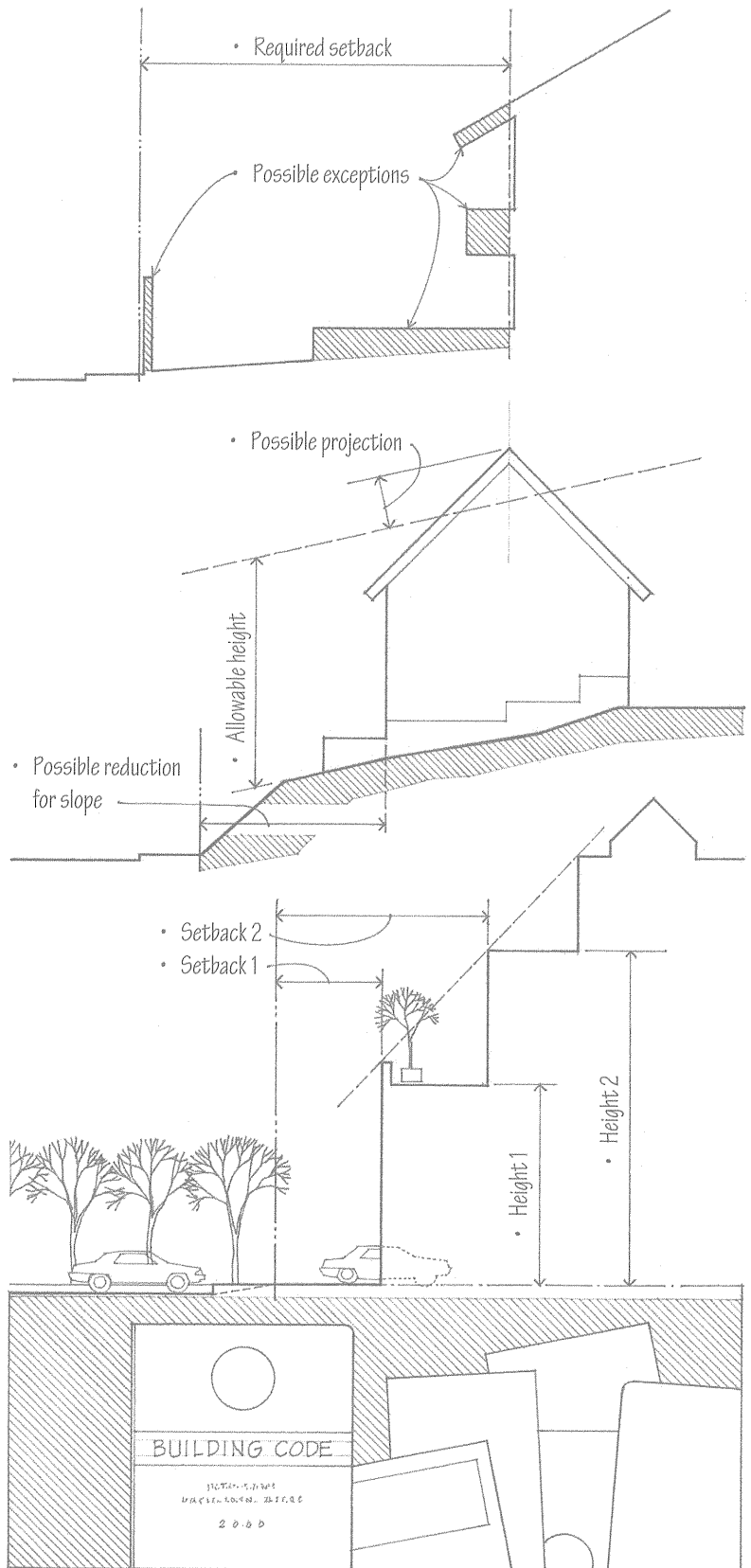
Zoning ordinances may also contain requirements that apply only to specific use categories as well as procedures for requesting a variance from the regulations.

- Restrictive covenants are provisions in a deed that restrict the action of any party to it, as an agreement among property owners specifying the use to which a property can be put. Racial and religious restrictions are legally unenforceable.

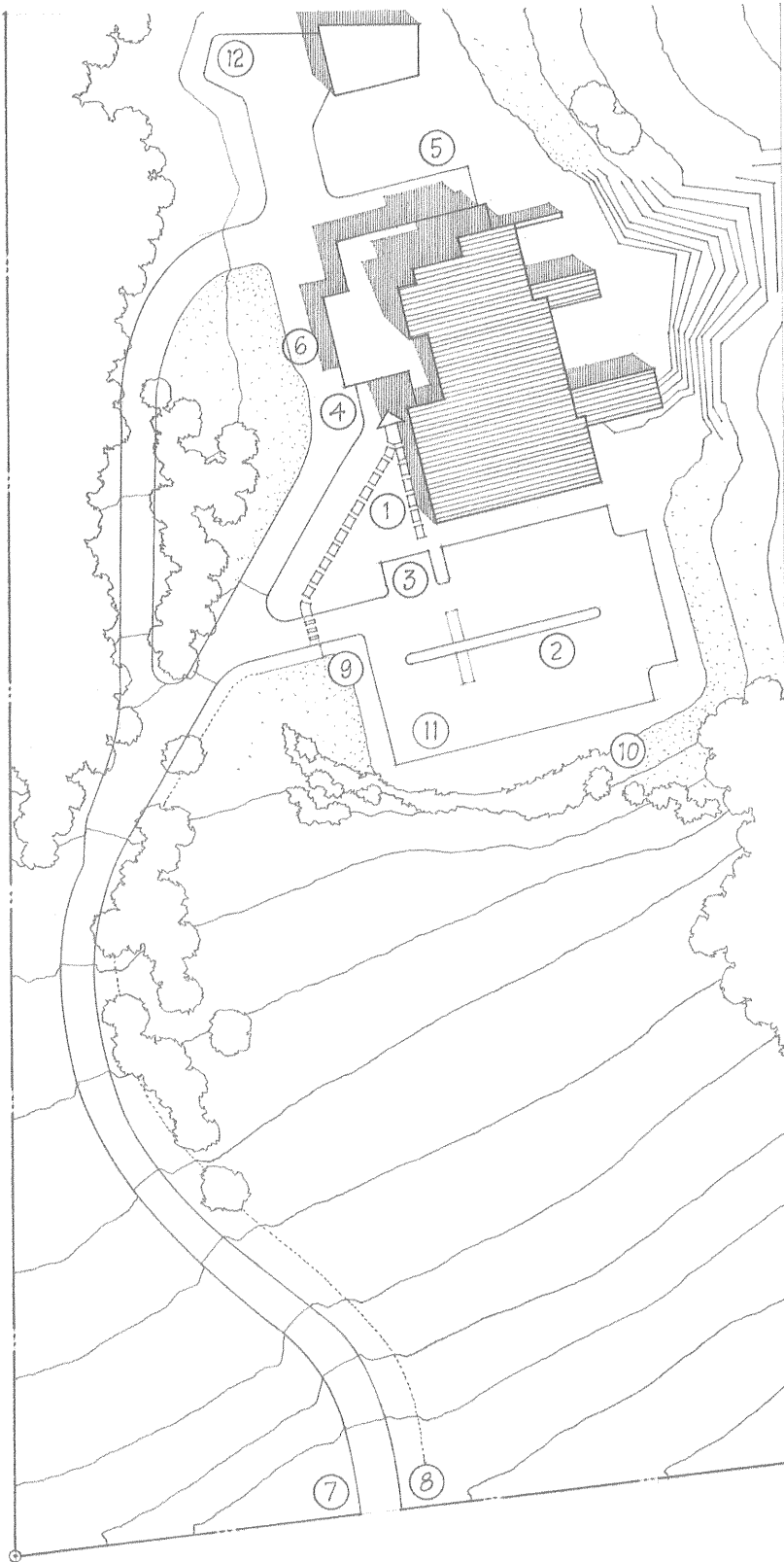
Other regulatory instruments exist that affect the way buildings are sited and constructed. These statutes—commonly referred to as the building code—establish the relationship between:

- The type of occupancy a building houses
- The fire-resistance rating of its structure and construction
- The allowable height and floor areas of the building, and its separation from neighboring structures

- See 2.05 for more information on building codes.



1.26 SITE ACCESS & CIRCULATION

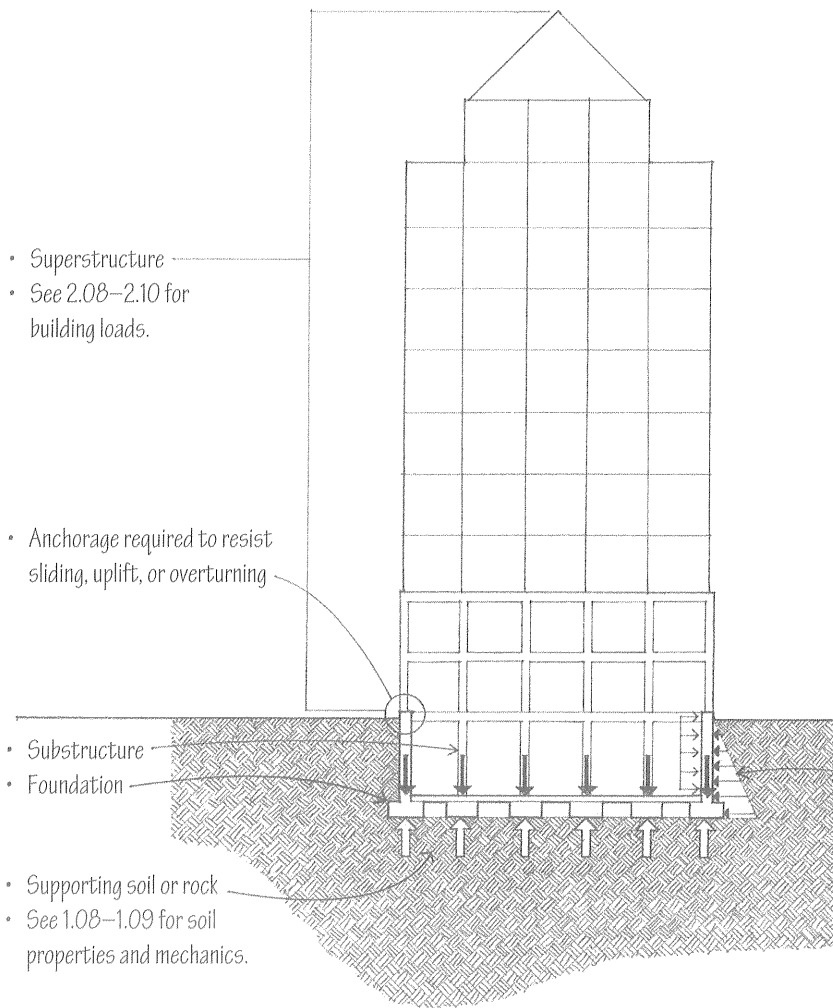


Providing for access and circulation for pedestrians, automobiles, and service vehicles is an important aspect of site planning, which influences both the location of a building on its site and the orientation of its entrances. Outlined here and on the following pages are fundamental criteria for estimating and laying out the space required for walkways, roadways, and surface parking.

1. Provide for safe and convenient pedestrian access and movement to building entrances from parking areas or public transit stops with minimal crossing of roadways.
2. Determine the number of parking spaces required by the zoning ordinance for the type of occupancy and total number of units or floor area of the building.
3. Determine the number of accessible parking spaces as well as curb cuts, ramps, and paths to accessible building entrances required by local, state, or federal law.
4. Provide loading zones for buses and other public transportation vehicles where applicable.
5. Separate service and truck loading areas from pedestrian and automobile traffic.
6. Furnish access for emergency vehicles such as fire trucks and ambulances.
7. Establish the required width and location of curb cuts and their proper distance from public street intersections.
8. Ensure clear sight lines for vehicles entering public roadways.
9. Plan for control of access to parking areas where required.
10. Provide space for landscaping; screening of parking areas may be required by zoning ordinance.
11. Slope paved walkways and parking areas for drainage.
12. Provide space for snow removal equipment in cold climates.

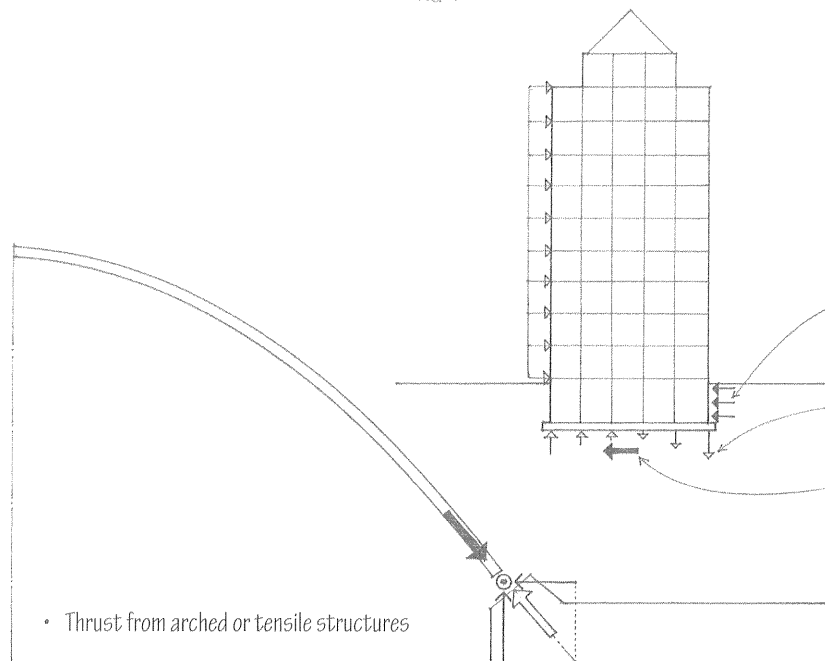
• Illustration adapted from the site plan for the Carré House, designed by Alvar Aalto.

3.02 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.



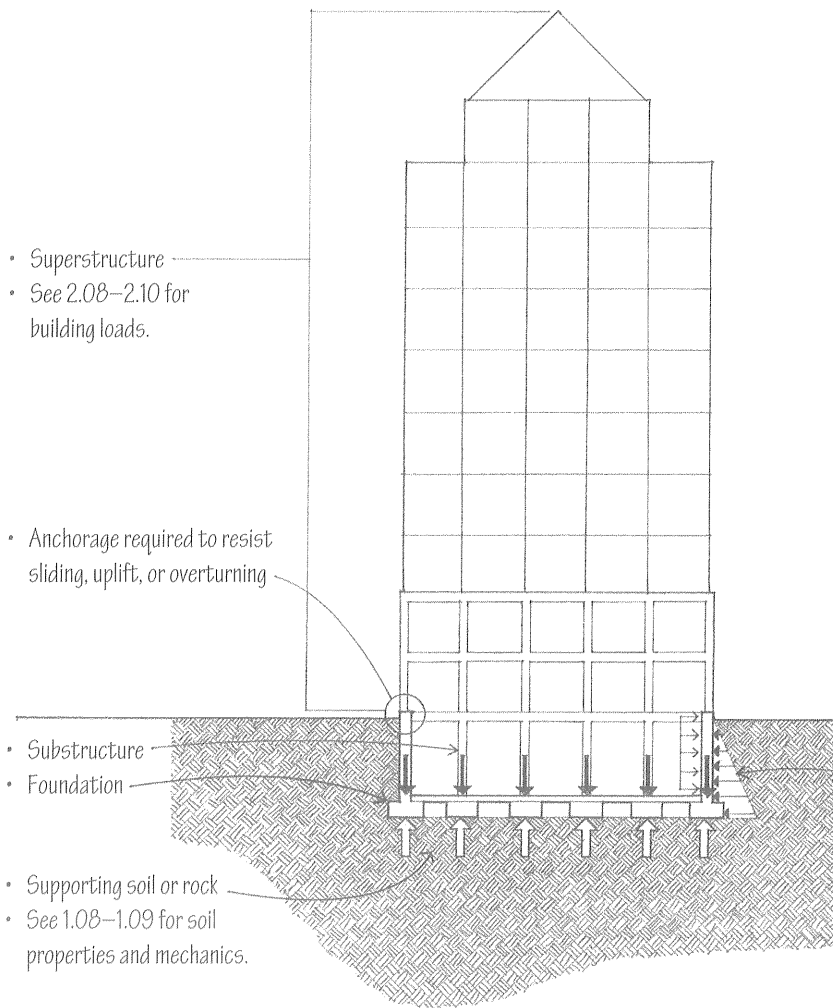
Active earth pressure exerted by a soil mass on a basement wall

3

FOUNDATION SYSTEMS

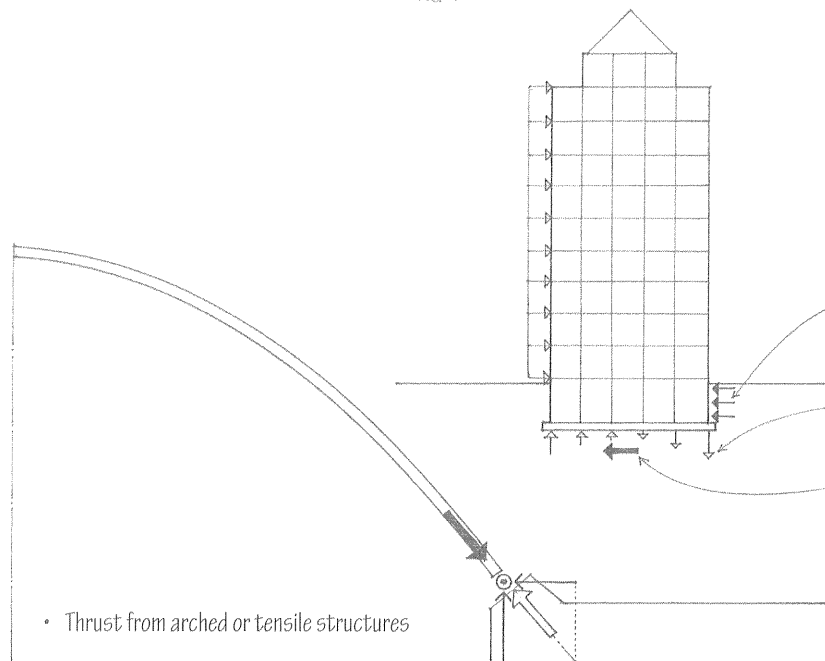
- 3.02 Foundation Systems
- 3.04 Types of Foundation Systems
- 3.06 Underpinning
- 3.07 Excavation Support Systems
- 3.08 Shallow Foundations
- 3.09 Spread Footings
- 3.10 Foundation Walls
- 3.16 Column Footings
- 3.17 Foundations on Sloping Ground
- 3.18 Concrete Slabs on Grade
- 3.22 Pole Foundations
- 3.24 Deep Foundations
- 3.25 Pile Foundations
- 3.26 Caisson Foundations

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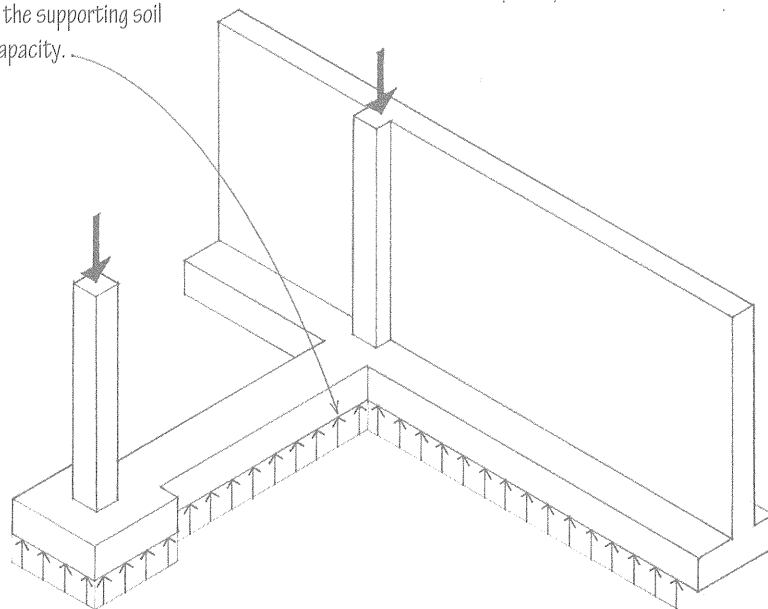
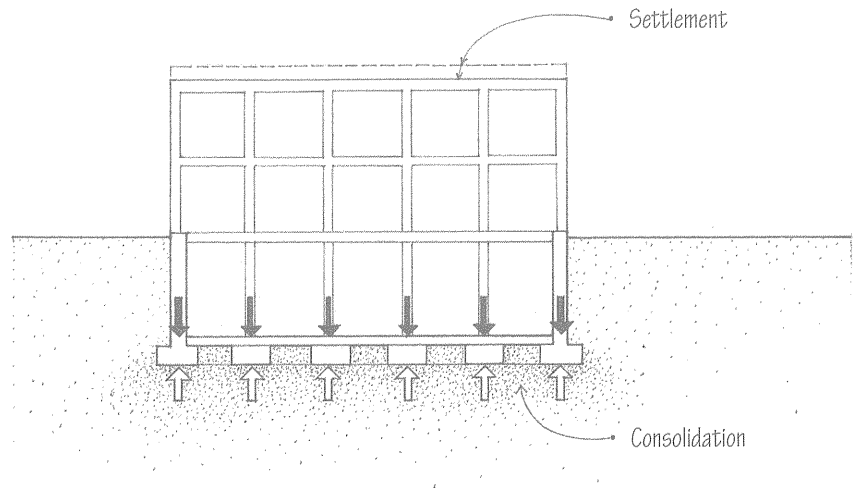
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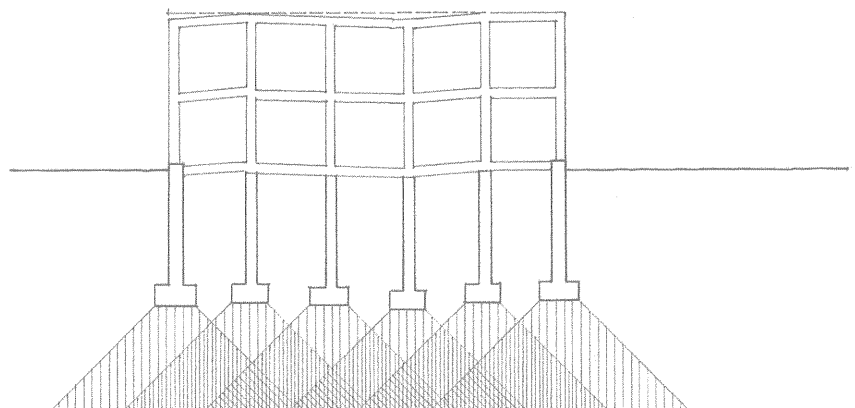
Active earth pressure exerted by a soil mass on a basement wall

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.

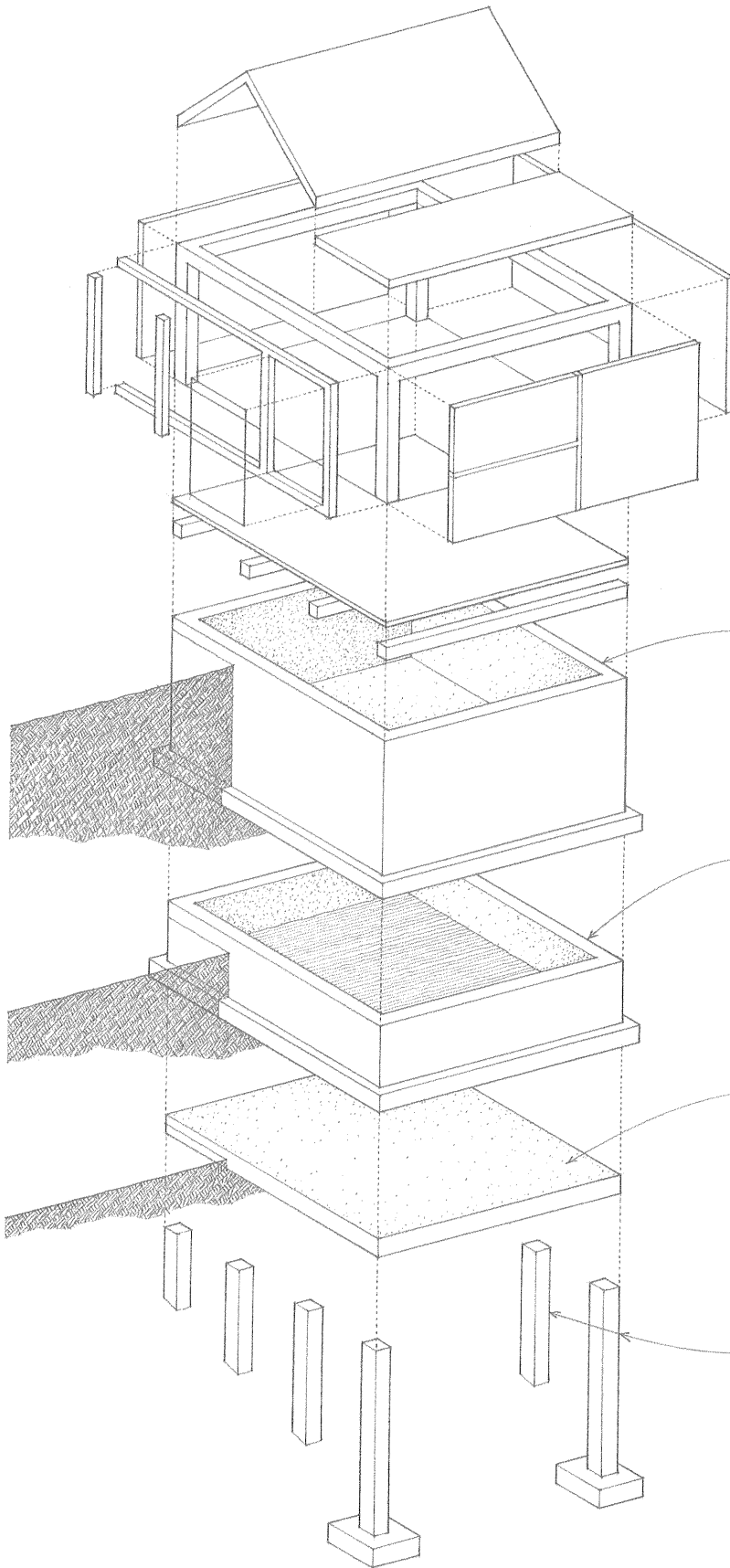


Differential settlement—the relative movement of different parts of a structure caused by uneven consolidation of the foundation soil—can cause a building to shift out of plumb and cracks to occur in its foundation, structure, or finishes. If extreme, differential settlement can result in the failure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



3.04 TYPES OF FOUNDATION SYSTEMS

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.

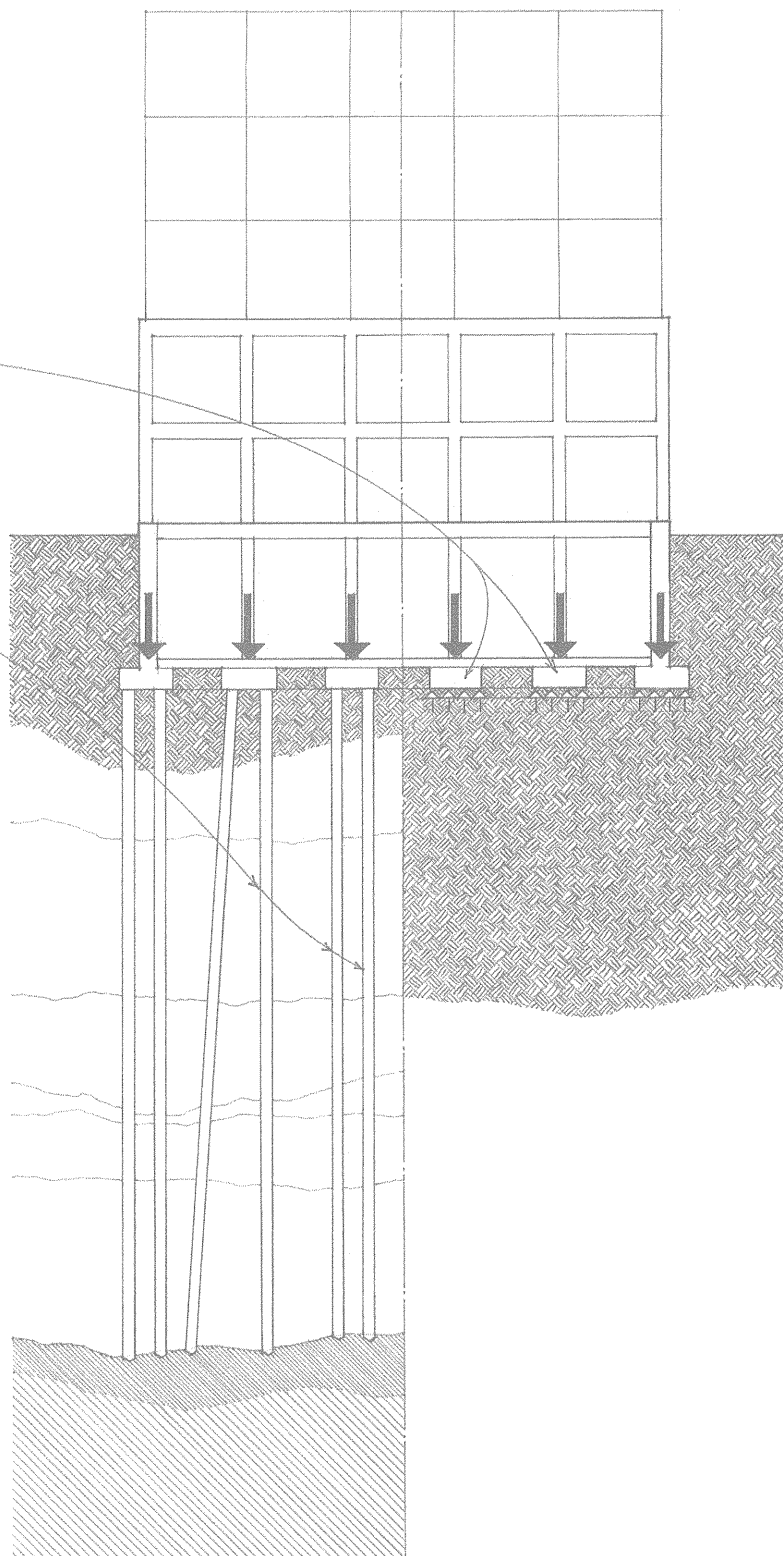
Deep Foundations

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:

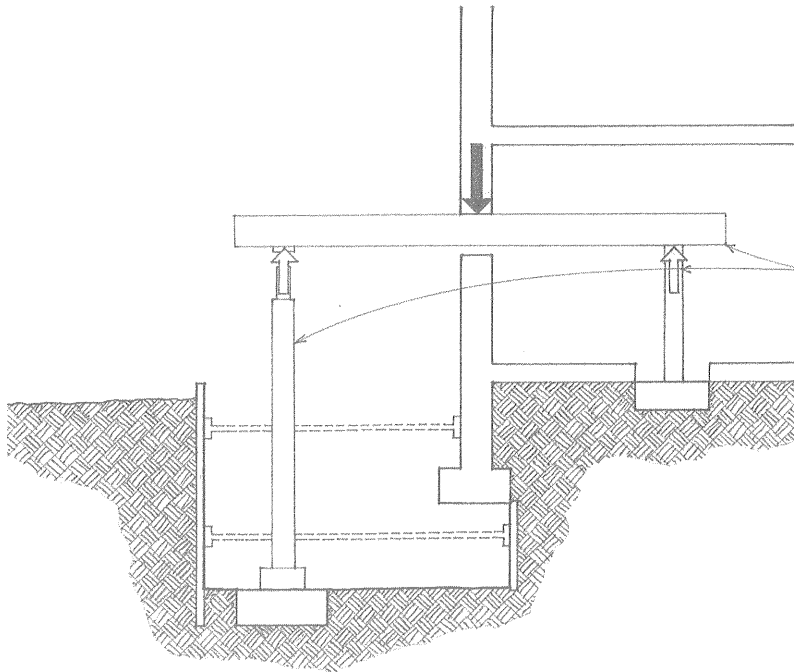
- Pattern and magnitude of building loads
- Subsurface and groundwater conditions
- Topography of the site
- Impact on adjacent properties
- Building code requirements
- Construction method and risk

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.

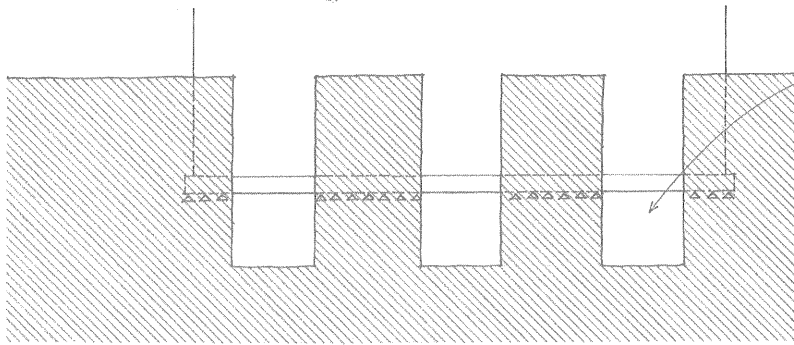


3.06 UNDERPINNING

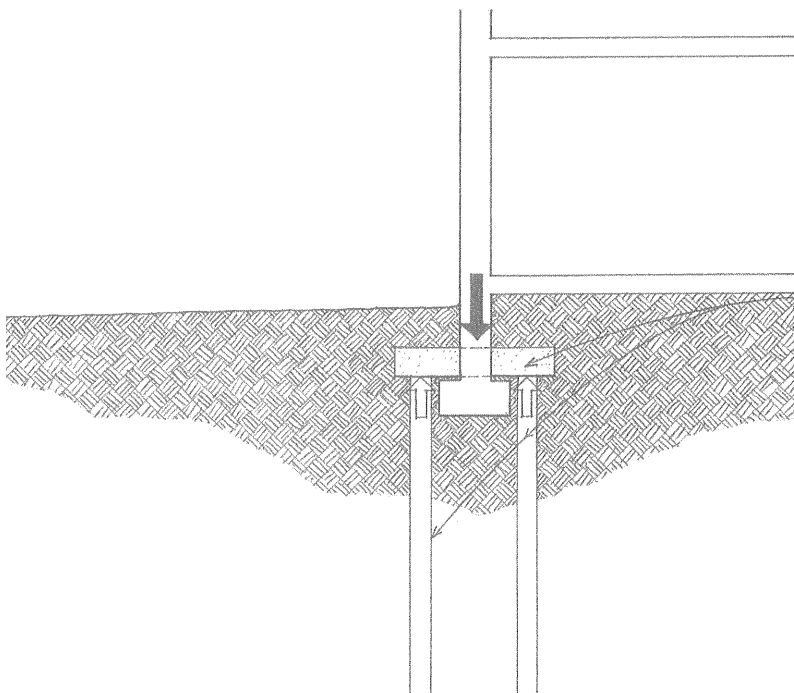
Underpinning refers to the process of rebuilding or strengthening the foundation of an existing building, or extending it when a new excavation in adjoining property is deeper than the existing foundation.



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.

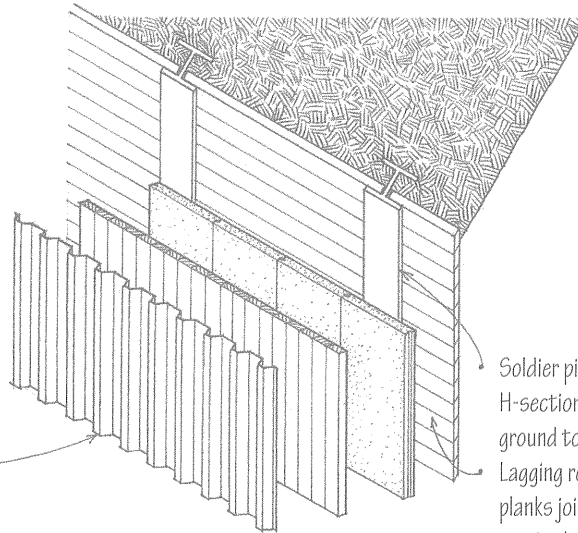


Another method for providing temporary support is to dig intermittent pits under the existing foundation down to the level of the new footings. After the new foundation wall and footing sections are placed, additional pits are dug until the entire wall has been deepened.



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.

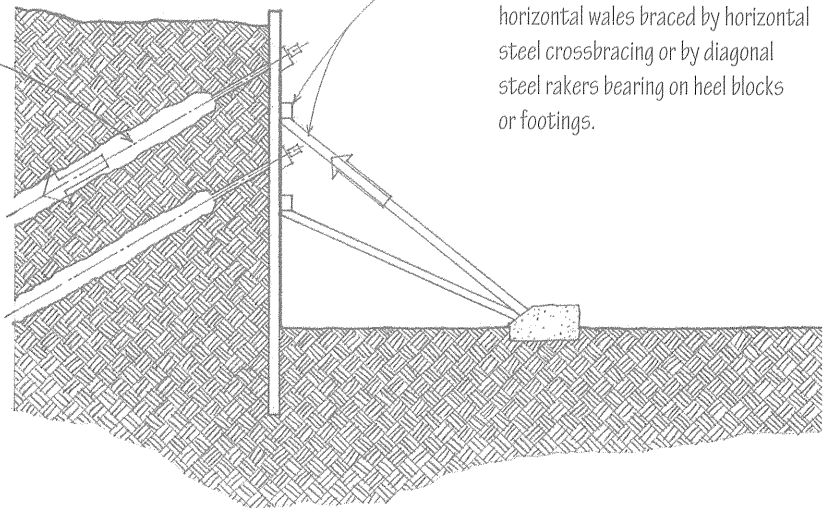
When the building site is sufficiently large that the sides of an excavation can be bench terraced or sloped at an angle less than the angle of repose for the soil, no supporting structure is necessary. When the sides of a deep excavation exceed the angle of repose for the soil, however, the earth must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

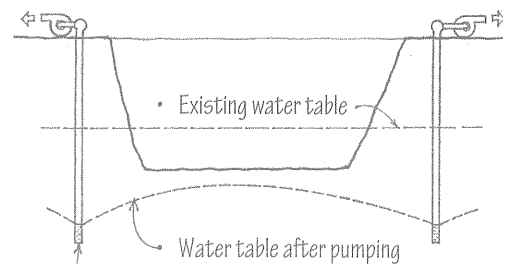
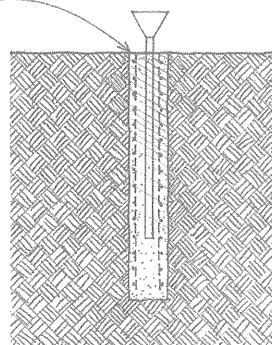
Soldier piles or beams are steel H-sections driven vertically into the ground to support horizontal lagging. Lagging refers to the heavy timber planks joined together side by side to retain the face of an excavation.

- 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.



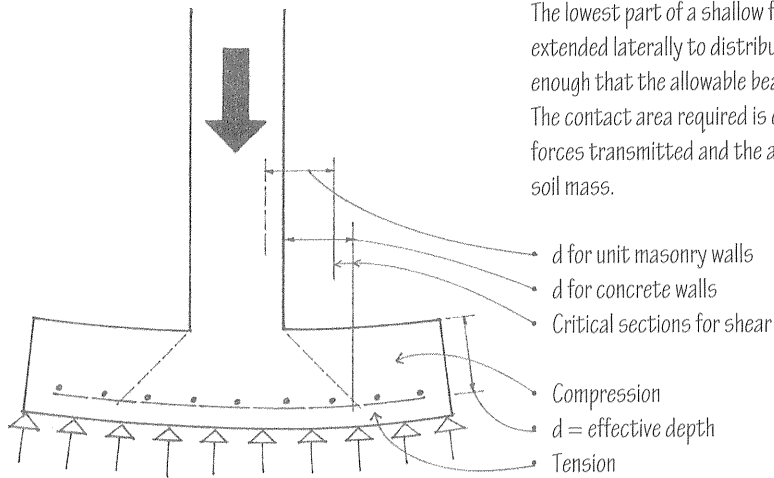
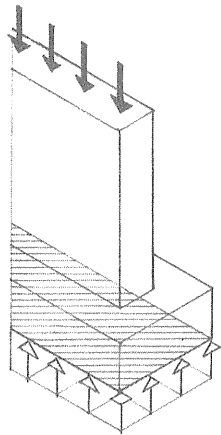
Sheet piling and soldier beams with lagging are supported with continuous horizontal wales braced by horizontal steel crossbracing or by diagonal steel rakers bearing on heel blocks or footings.

- 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.

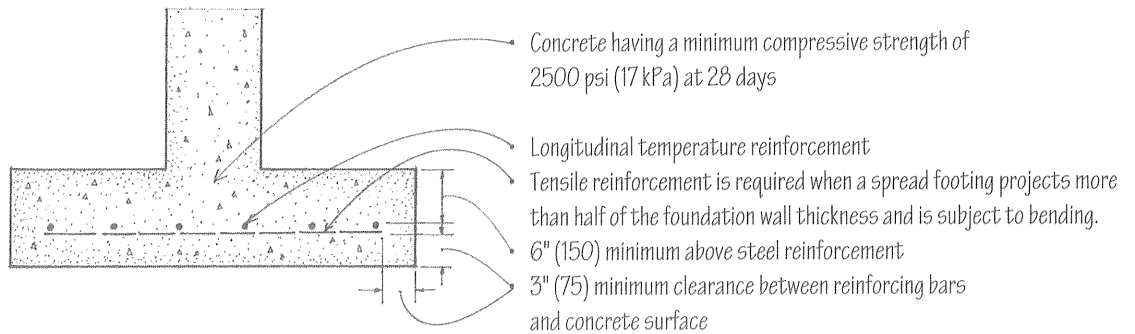


- Dewatering (CSI 31 23 19) refers to the process of lowering a water table or preventing an excavation from filling with groundwater. It is accomplished by driving perforated tubes called wellpoints into the ground to collect water from the surrounding area so it can be pumped away.

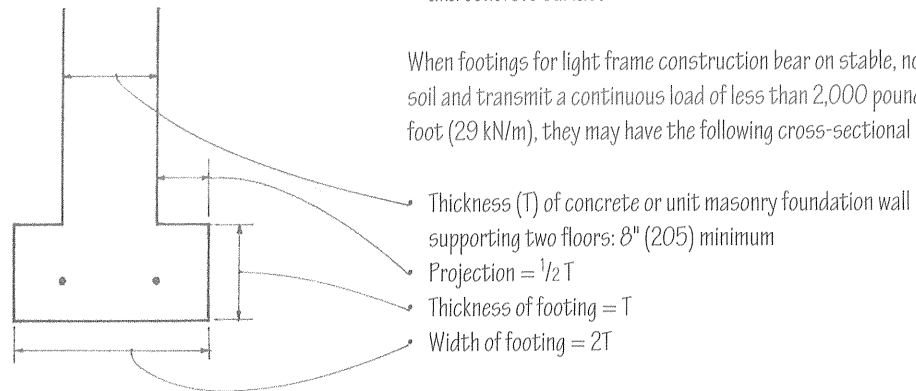
3.08 SHALLOW FOUNDATIONS



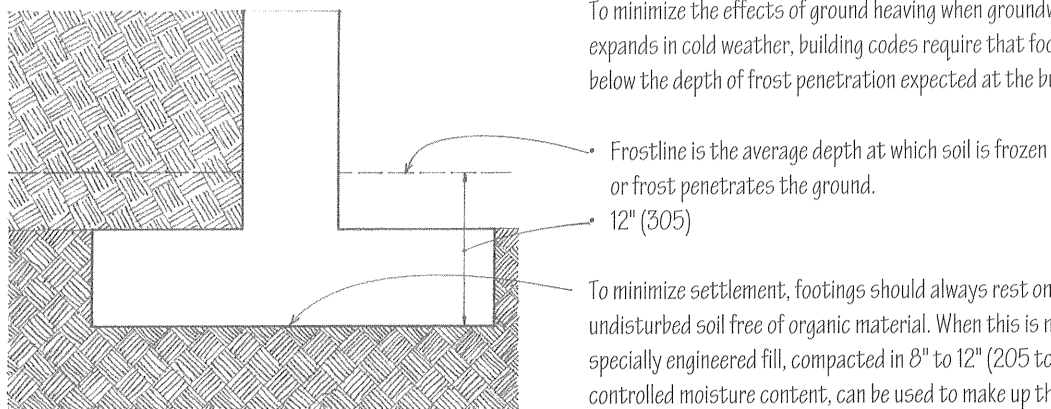
The lowest part of a shallow foundation are spread footings. They are extended laterally to distribute their load over an area of soil wide enough that the allowable bearing capacity of the soil is not exceeded. The contact area required is equal to the quotient of the magnitude of forces transmitted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



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.



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.

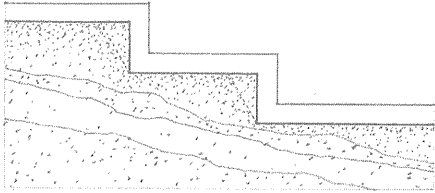


To minimize settlement, footings should always rest on stable, undisturbed soil free of organic material. When this is not possible, a specially engineered fill, compacted in 8" to 12" (205 to 305) layers at a controlled moisture content, can be used to make up the extra depth.

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

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

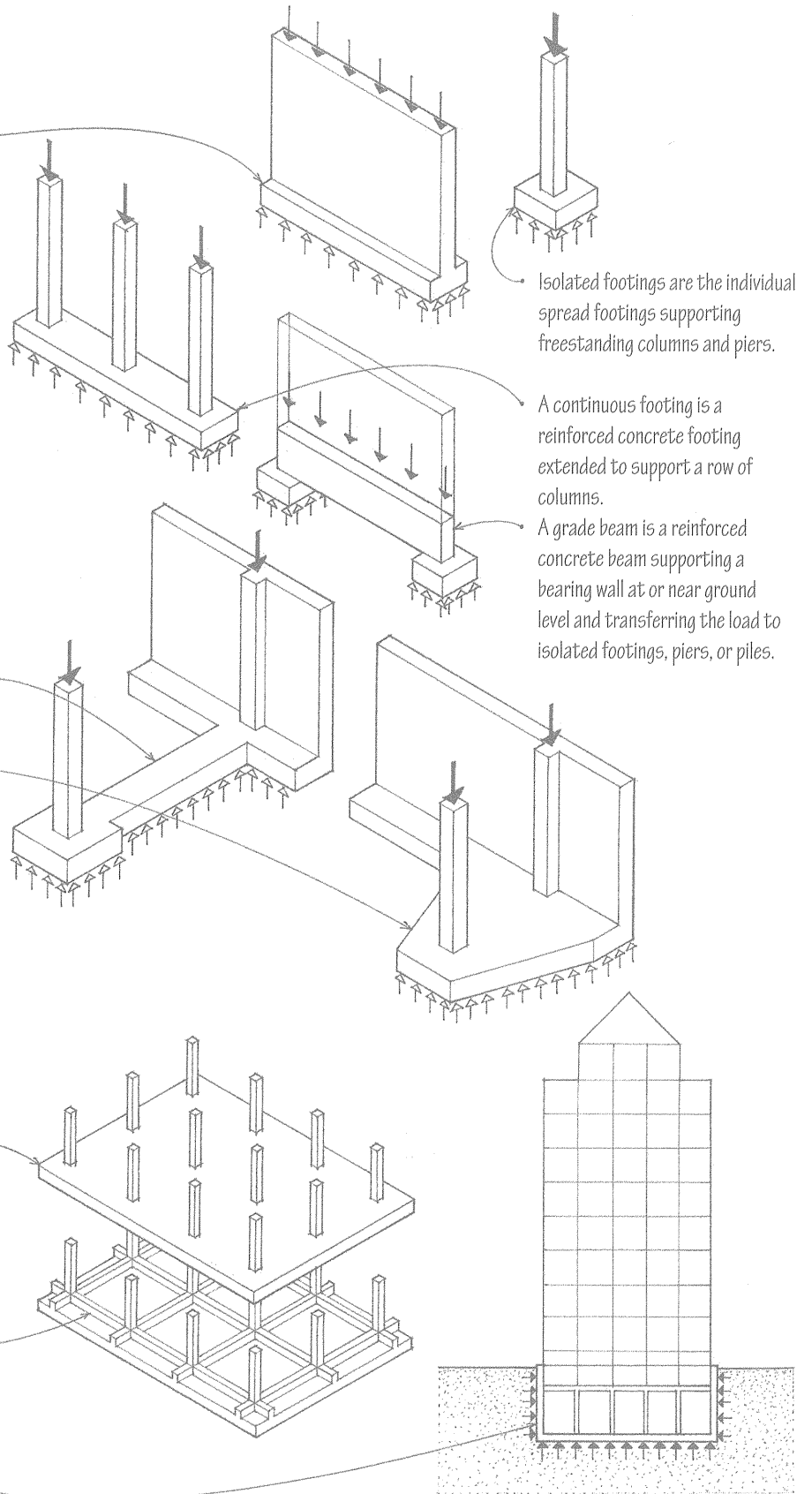
Other types of spread footings include the following:



- 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 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.

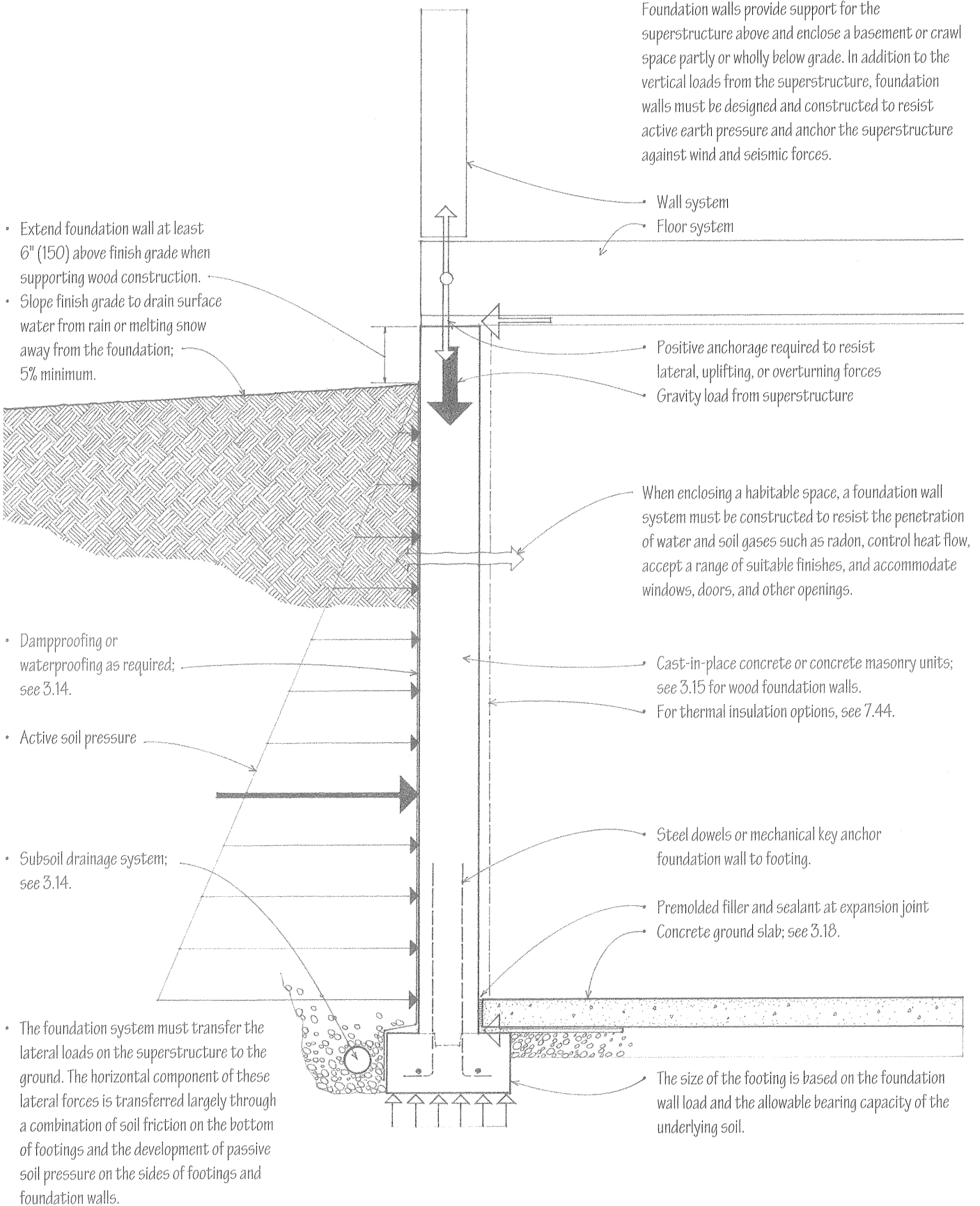


Isolated footings are the individual spread footings supporting freestanding columns and piers.

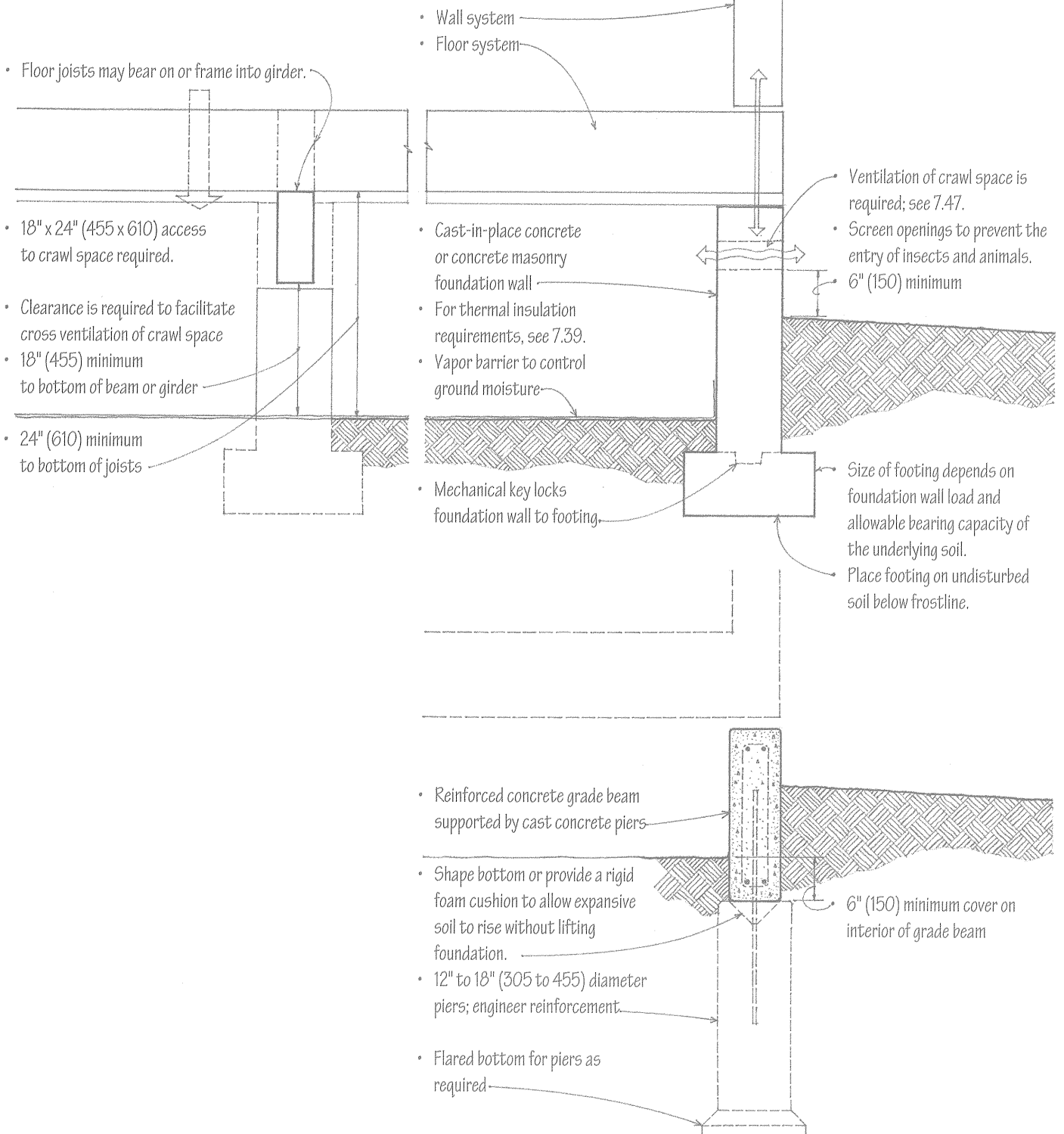
A continuous footing is a reinforced concrete footing extended to support a row of columns.

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.

3.10 FOUNDATION WALLS



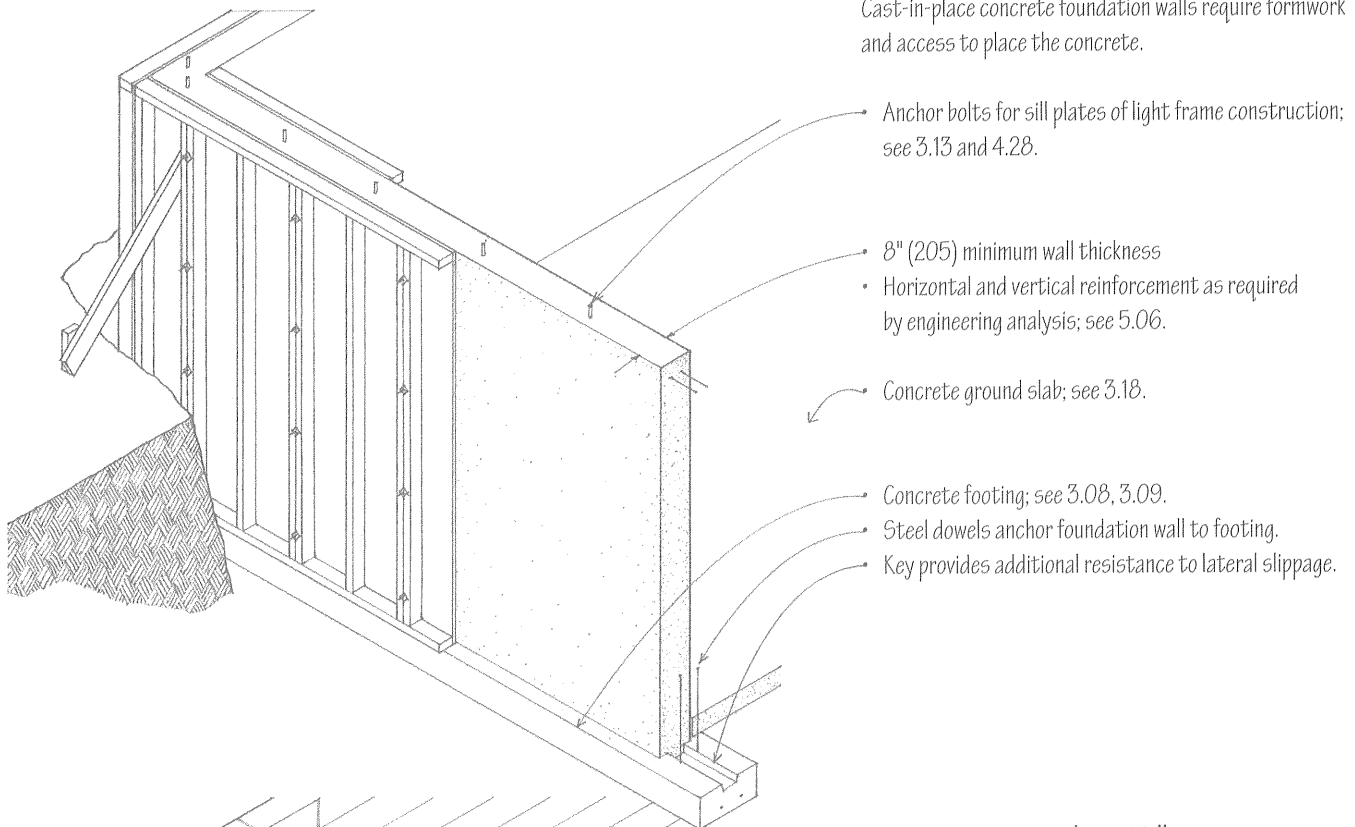
Crawl spaces enclosed by a continuous foundation wall or piers provide space under a first floor for the integration of and access to mechanical, electrical, and plumbing installations.



3.12 FOUNDATION WALLS

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.

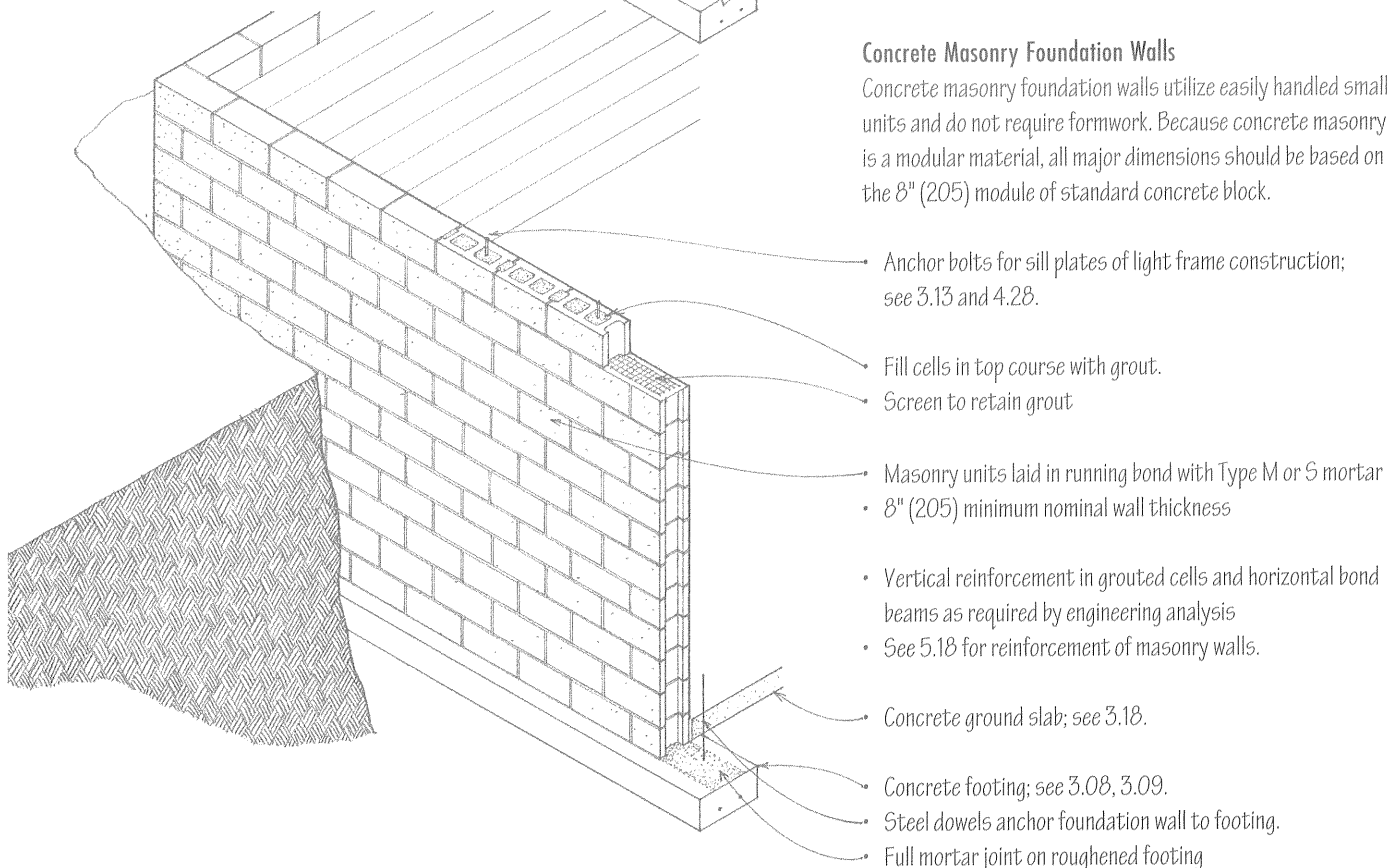
• Concrete footing; see 3.08, 3.09.

• 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.

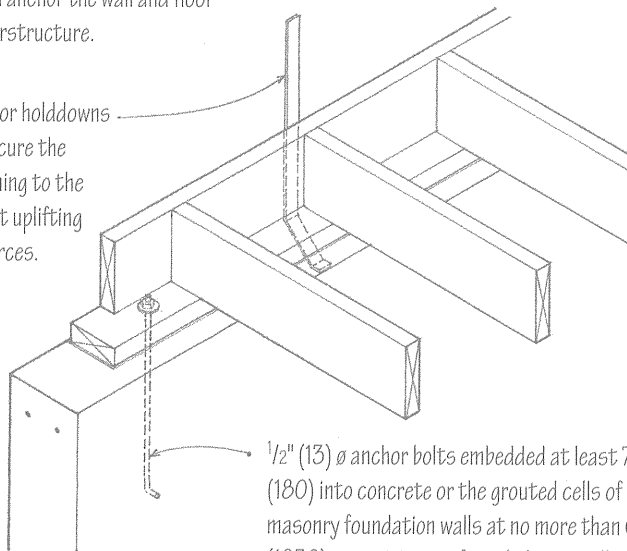
• Concrete footing; see 3.08, 3.09.

• Steel dowels anchor foundation wall to footing.

• Full mortar joint on roughened footing

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

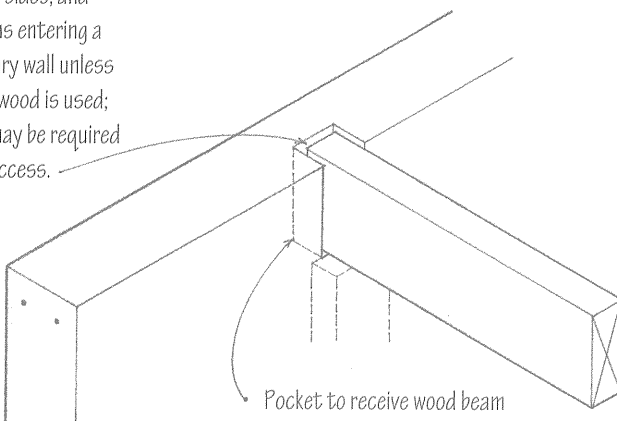
- Sill plate anchors or holddowns are required to secure the wall and floor framing to the foundation against uplifting wind or seismic forces.



$\frac{1}{2}$ " (13) \varnothing 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

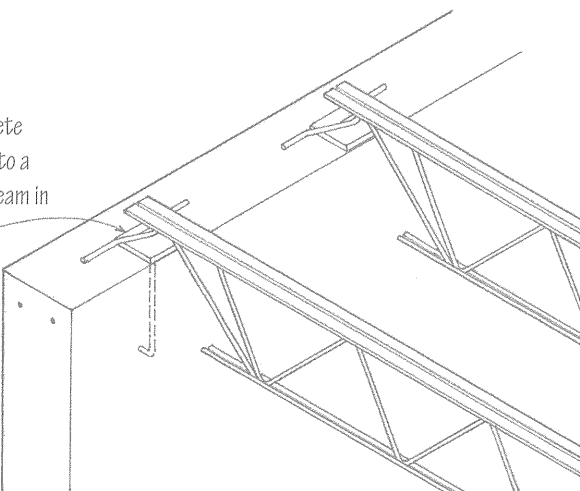
- Provide $\frac{1}{2}$ " (13) minimum air space on the tops, sides, and ends of wood beams entering a concrete or masonry wall unless pressure-treated wood is used; additional space may be required for construction access.



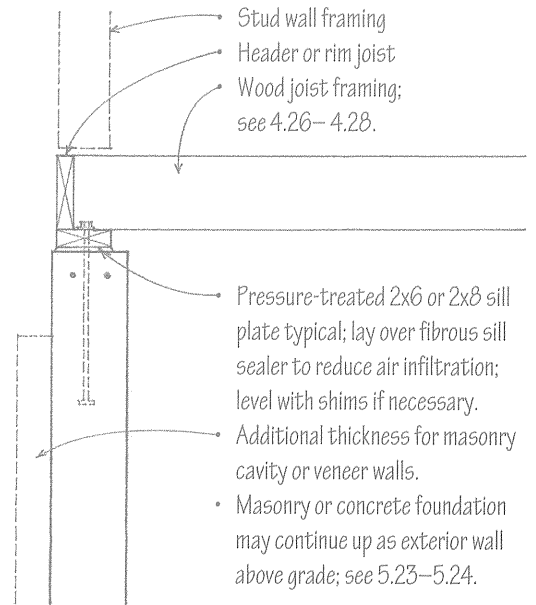
Pocket to receive wood beam

Wood Beams

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

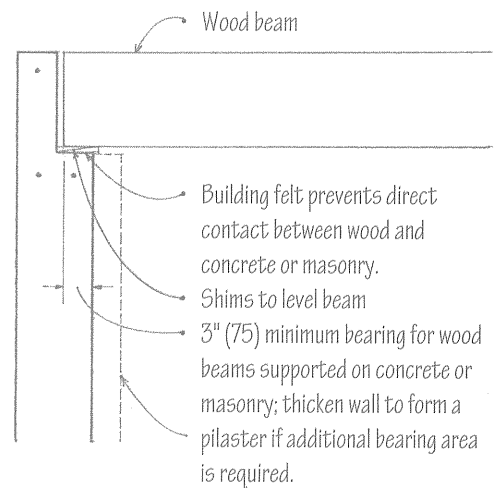


Open-Web Steel Joists

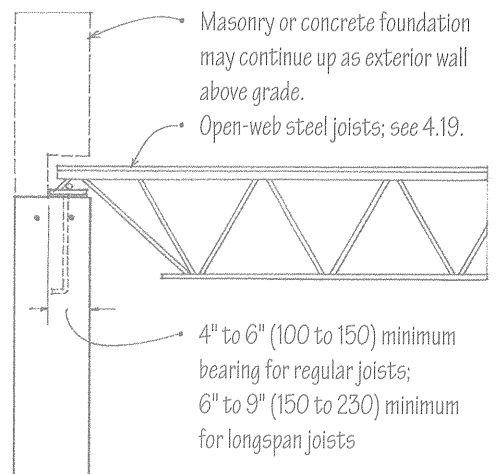


Stud wall framing
Header or rim joist
Wood joist framing; see 4.26–4.28.

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.



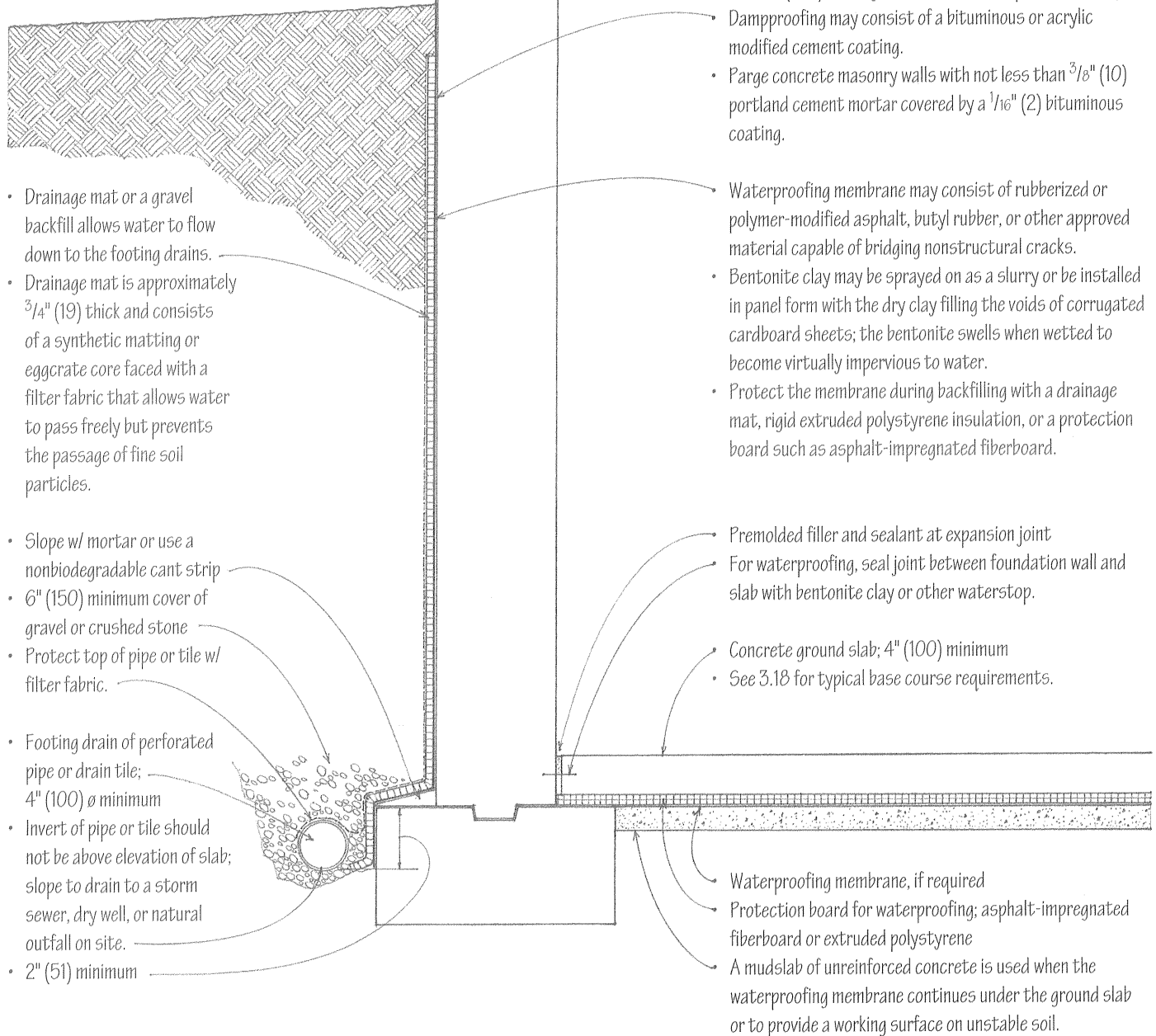
Wood beam
Building felt prevents direct contact between wood and concrete or masonry.
Shims to level beam
3" (75) minimum bearing for wood beams supported on concrete or masonry; thicken wall to form a pilaster if additional bearing area is required.



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

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.

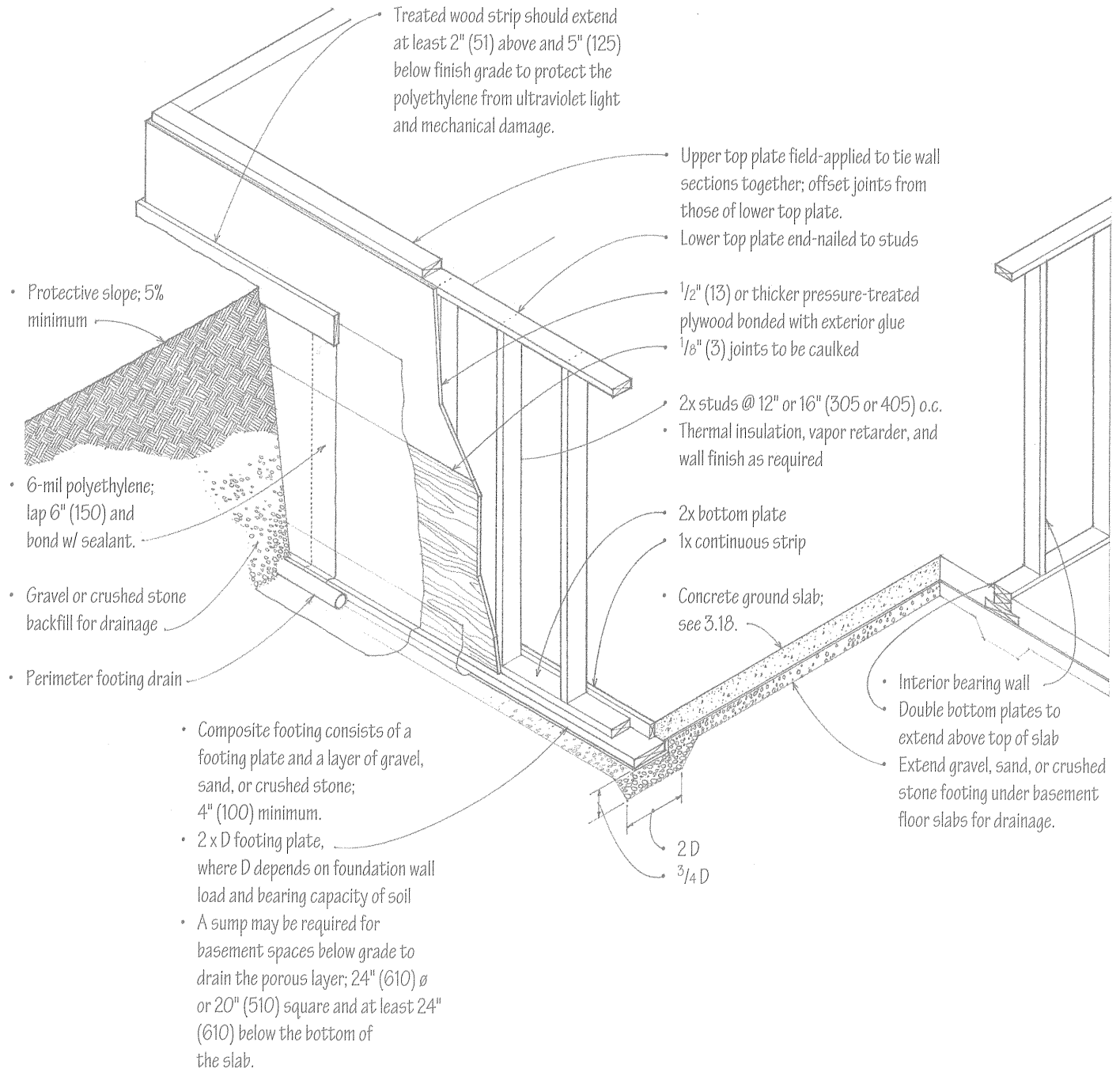


- Drainage mat or a gravel backfill allows water to flow down to the footing drains.
- Drainage mat is approximately 3/4" (19) thick and consists of a synthetic matting or eggcrate core faced with a filter fabric that allows water to pass freely but prevents the passage of fine soil particles.
- Slope 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.
- Footing drain of perforated pipe or drain tile; 4" (100) ϕ 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

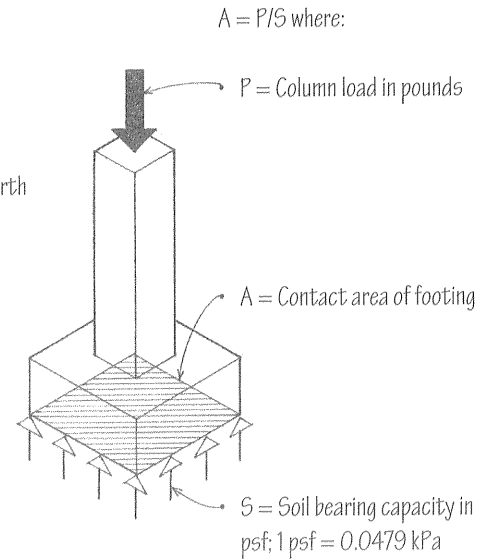
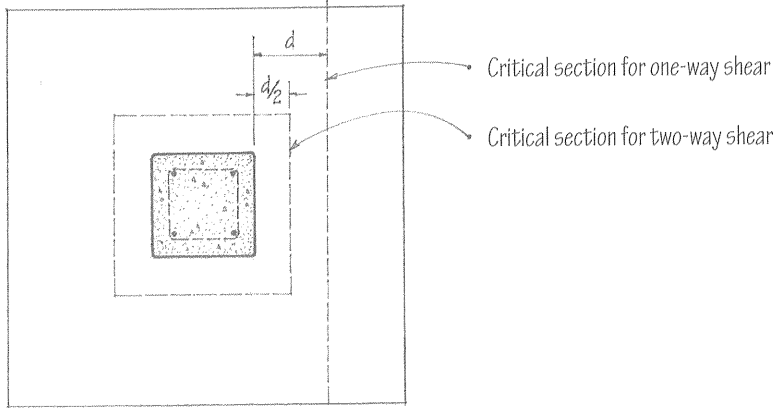
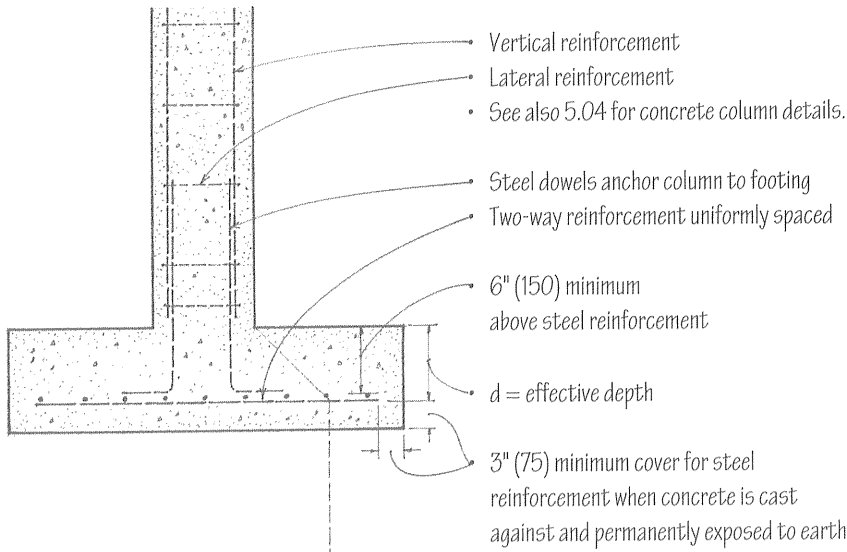
Dampproofing is applied to a foundation wall when subsoil conditions indicate that hydrostatic pressure from the groundwater table will not occur. When subject to hydrostatic pressure from the groundwater table, foundation walls should be waterproofed. Some building codes require that all foundation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

- 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.
- 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.
- 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.
- 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.

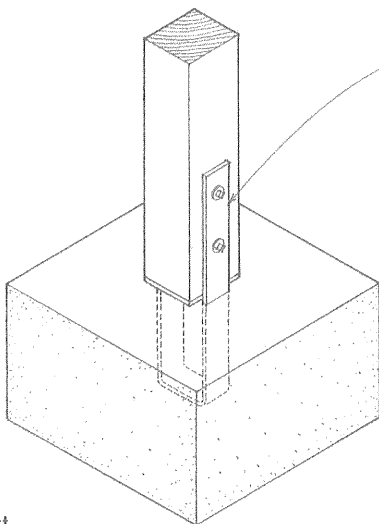
Treated wood foundation systems can be used for both basement and crawl space construction. The wall sections may be built on-site or be factory-fabricated to reduce erection time. All wood and plywood used to fabricate a foundation system must be pressure-treated with a preservative approved for ground 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.



3.16 COLUMN FOOTINGS

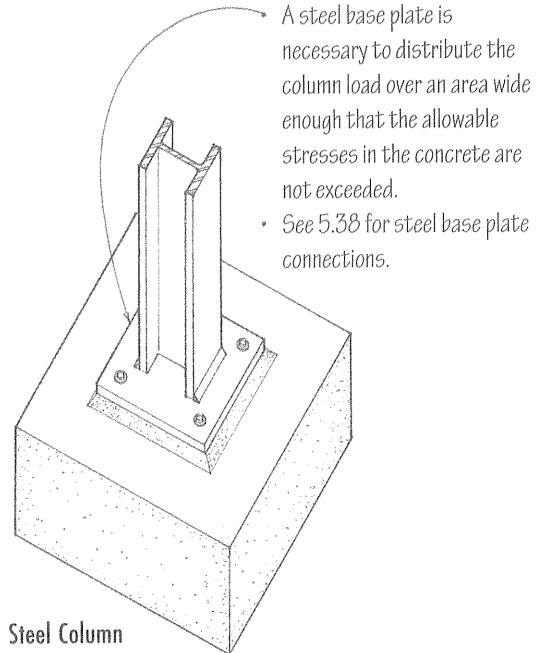


Reinforced Concrete Column



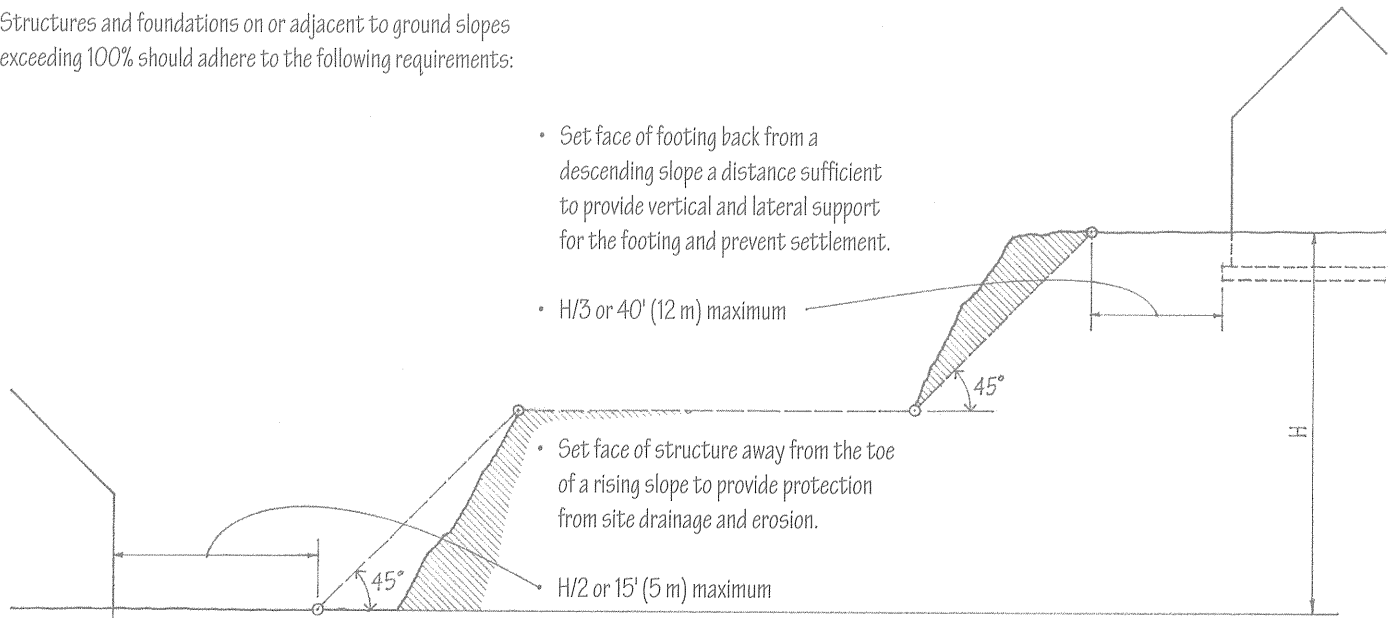
Wood Post

- 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.



Steel Column

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

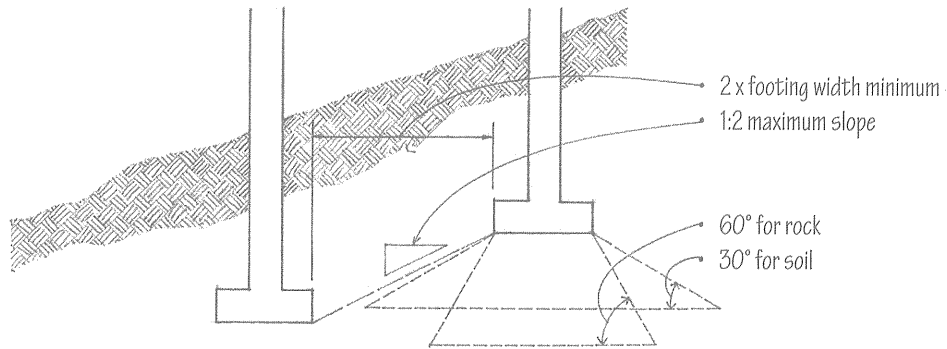


- Set face of footing back from a descending slope a distance sufficient to provide vertical and lateral support for the footing and prevent settlement.

• H/3 or 40' (12 m) maximum

- Set face of structure away from the toe of a rising slope to provide protection from site drainage and erosion.

• H/2 or 15' (5 m) maximum



• 2 x footing width minimum

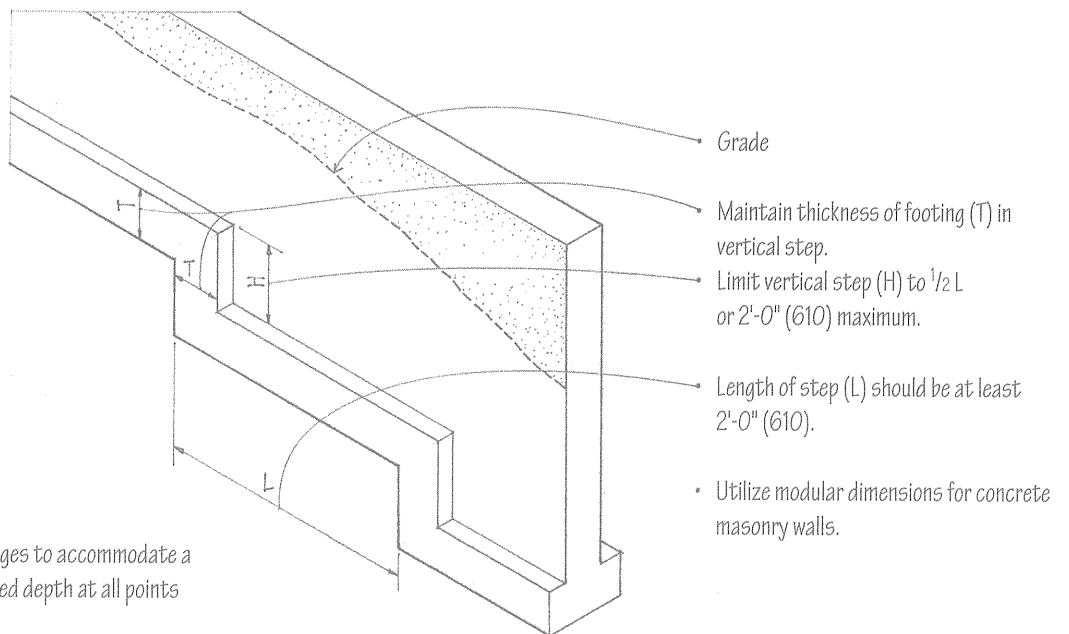
• 1:2 maximum slope

• 60° for rock

• 30° for soil

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.



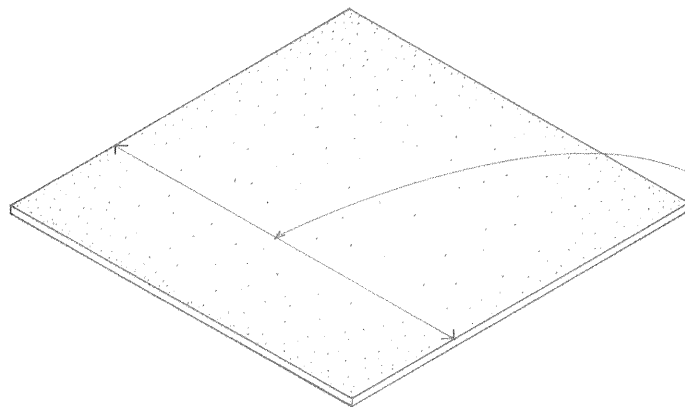
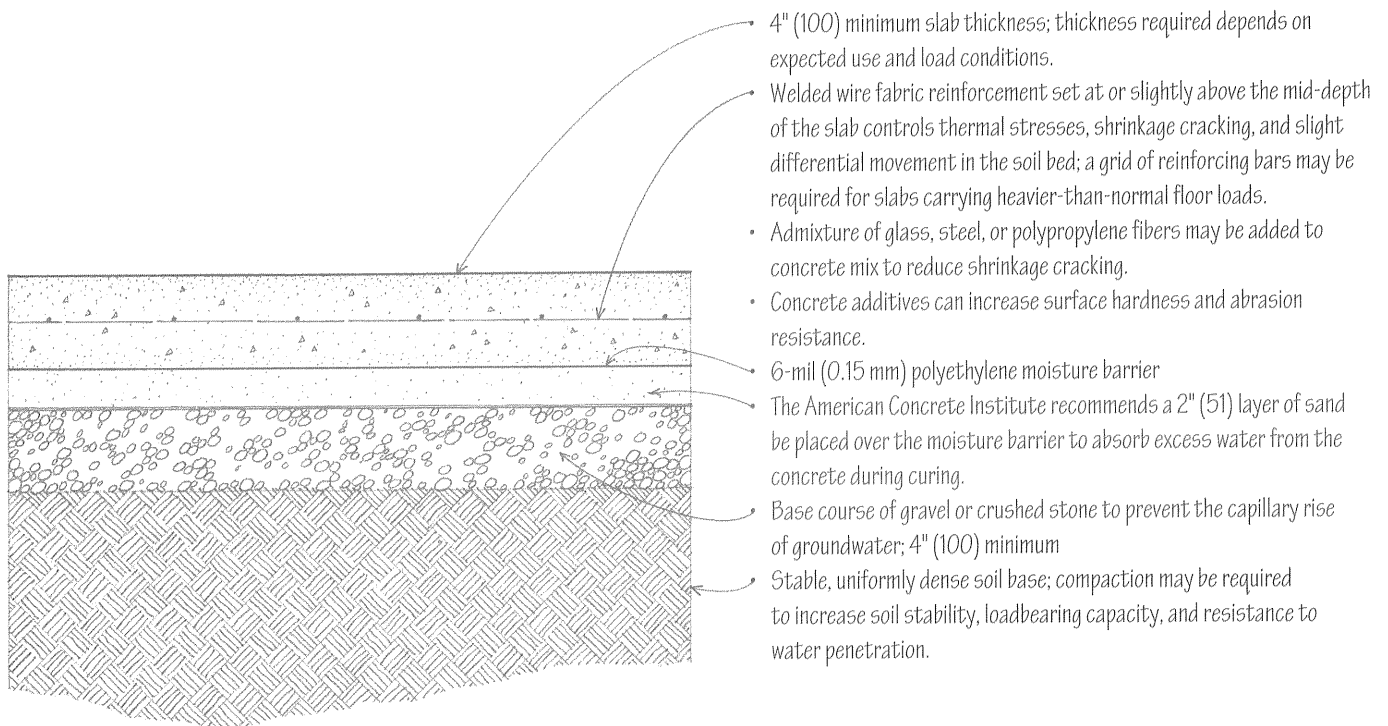
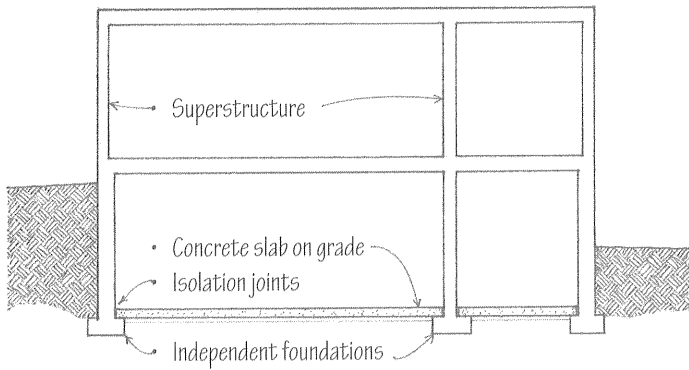
Stepped footings change levels in stages to accommodate a sloping grade and maintain the required depth at all points around a building.

- Utilize modular dimensions for concrete masonry walls.

3.18 CONCRETE SLABS ON GRADE

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.



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

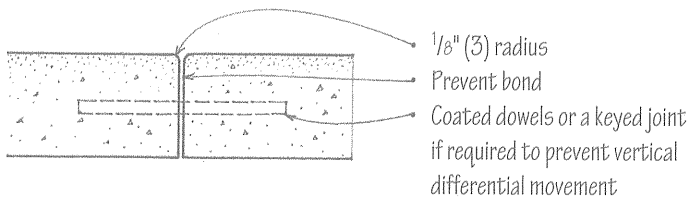
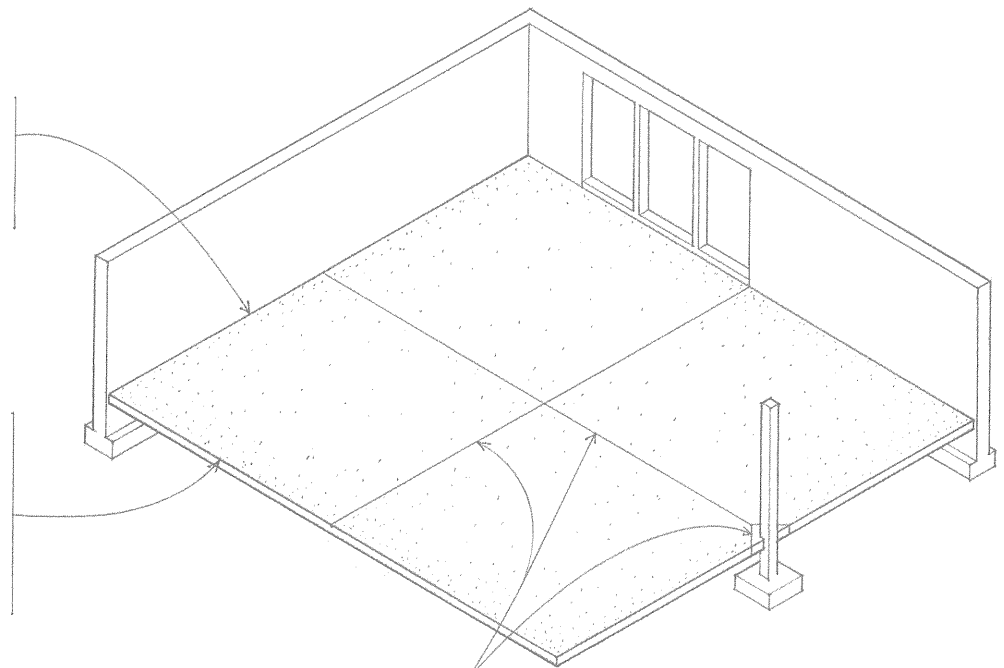
Three types of joints may be created or constructed in order to accommodate movement in the plane of a concrete slab on grade— isolation joints, construction joints, and control joints.

Isolation Joints

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

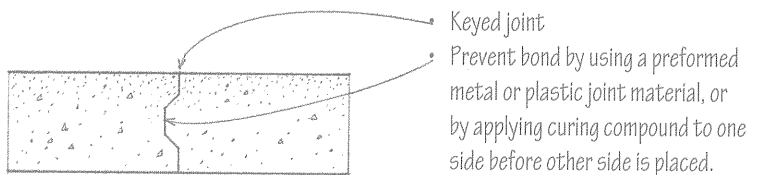
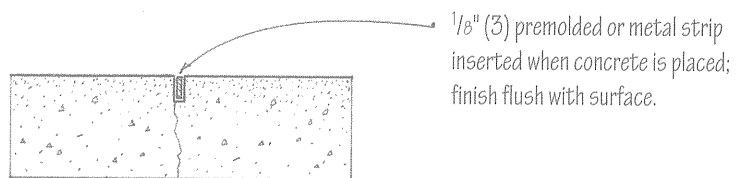
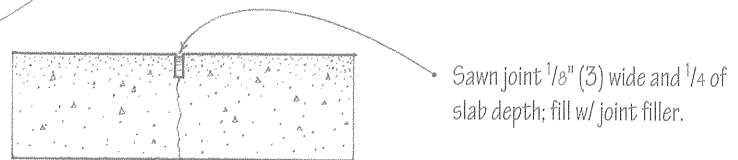
Construction Joints

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.

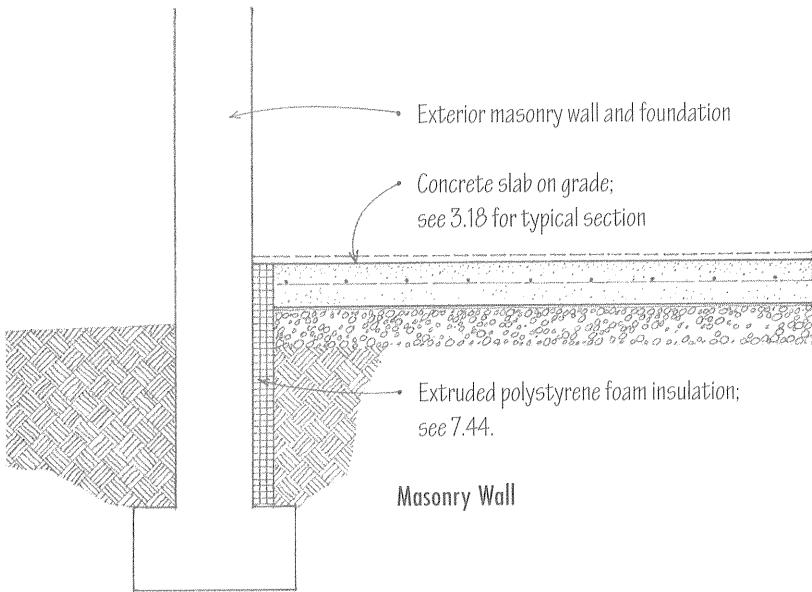


Control Joints

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.



3.20 CONCRETE SLABS ON GRADE

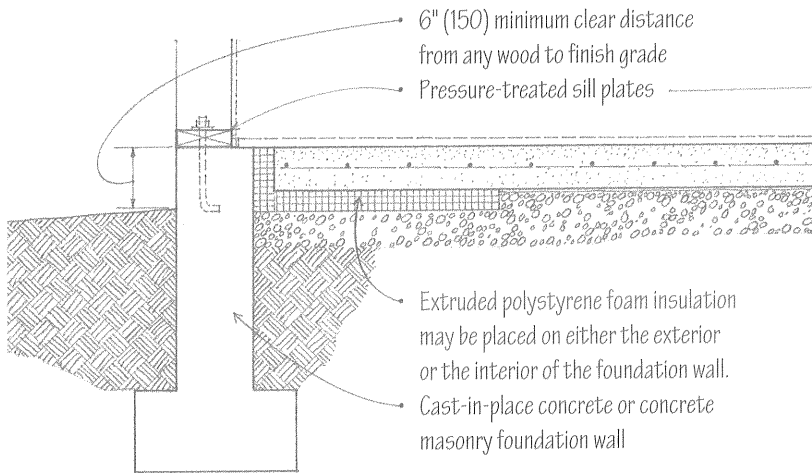


Exterior masonry wall and foundation

Concrete slab on grade;
see 3.18 for typical section

Extruded polystyrene foam insulation;
see 7.44.

Masonry Wall



6" (150) minimum clear distance
from any wood to finish grade

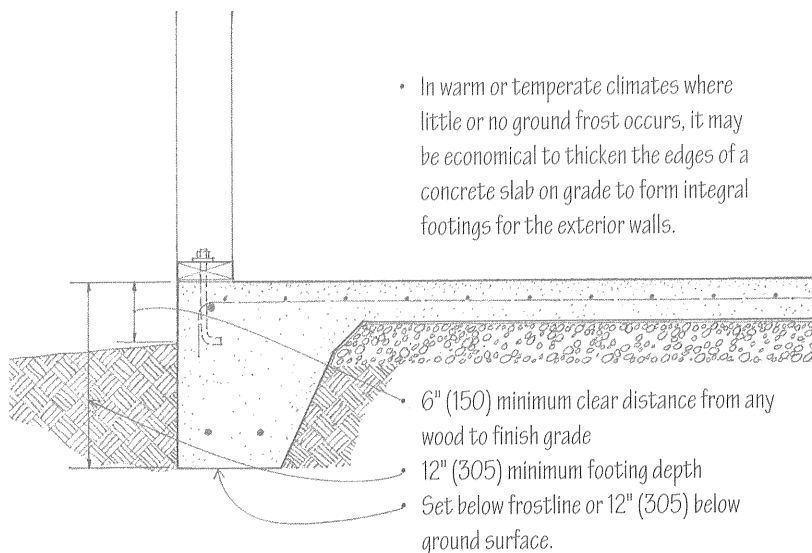
Pressure-treated sill plates

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

Cast-in-place concrete or concrete
masonry foundation wall

Stud Wall

- 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.



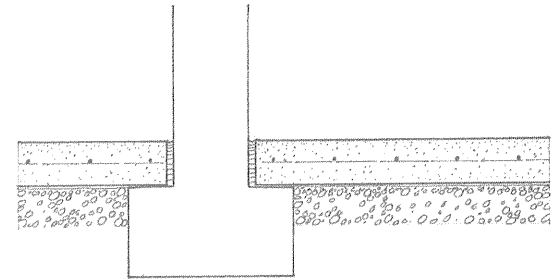
6" (150) minimum clear distance from any
wood to finish grade

12" (305) minimum footing depth

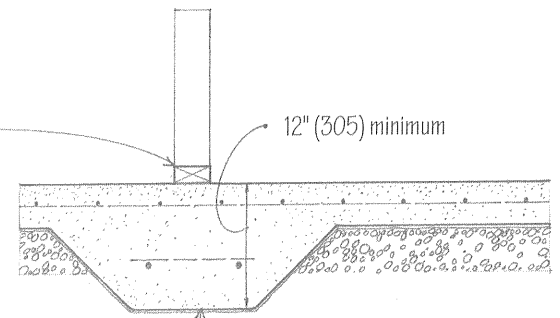
Set below frostline or 12" (305) below
ground surface.

Thickened Edge Slab

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



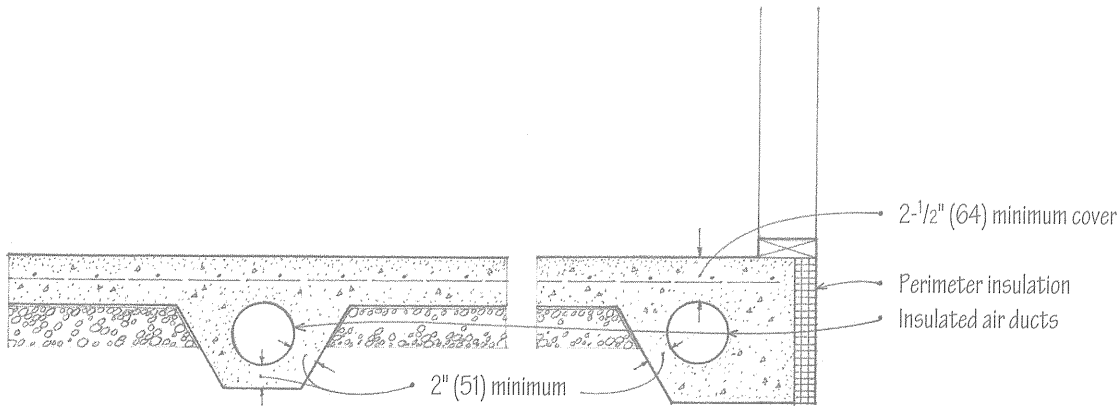
- An independent footing should be used when a bearing wall or column transmits a heavy or concentrated load.



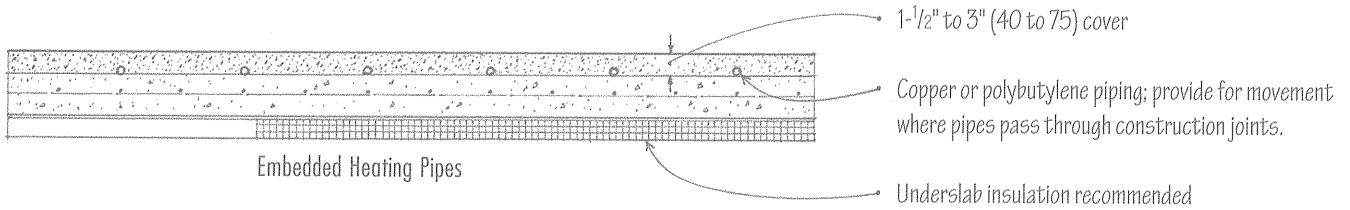
12" (305) minimum

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

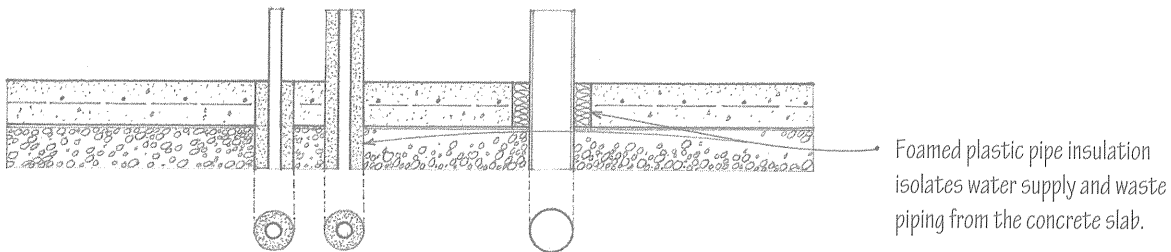
- A concrete ground slab may be thickened to support an interior bearing partition or post and transmit the load to the underlying soil.



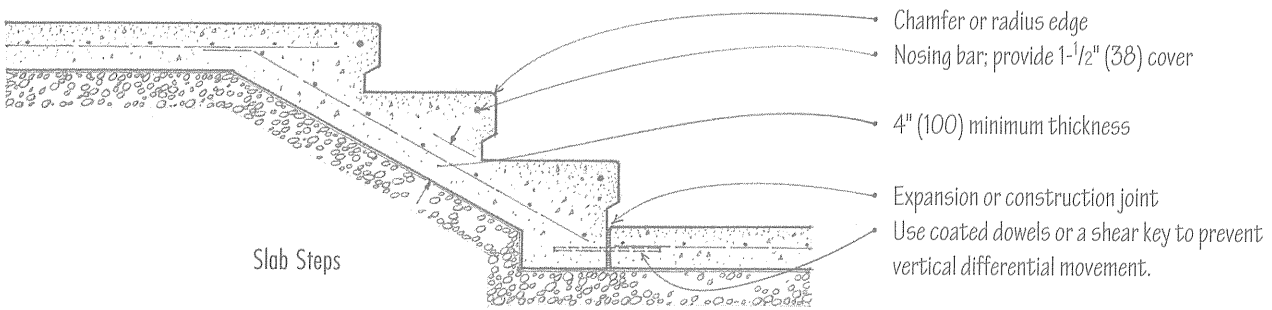
Heating Ducts



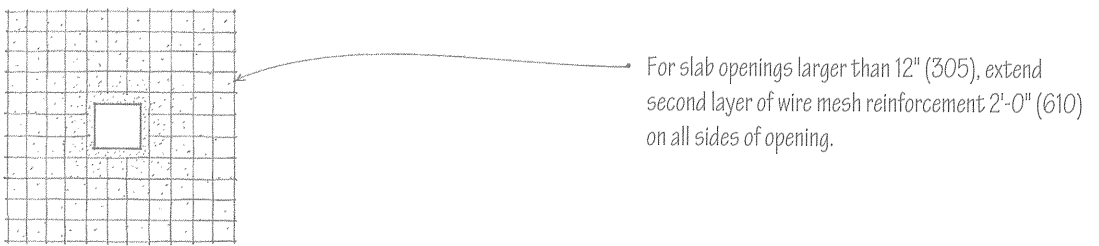
Embedded Heating Pipes



Pipe Penetrations



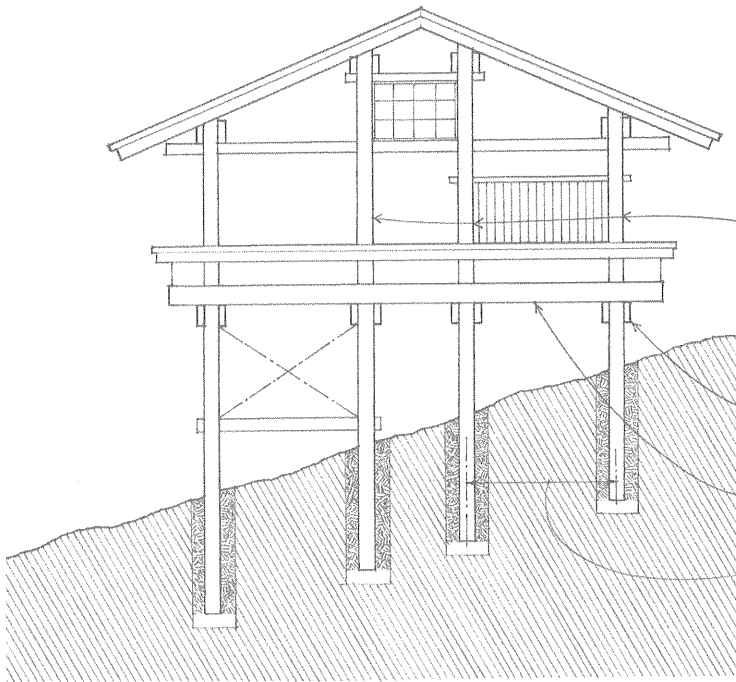
Slab Steps



Slab Openings

3.22 POLE FOUNDATIONS

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.

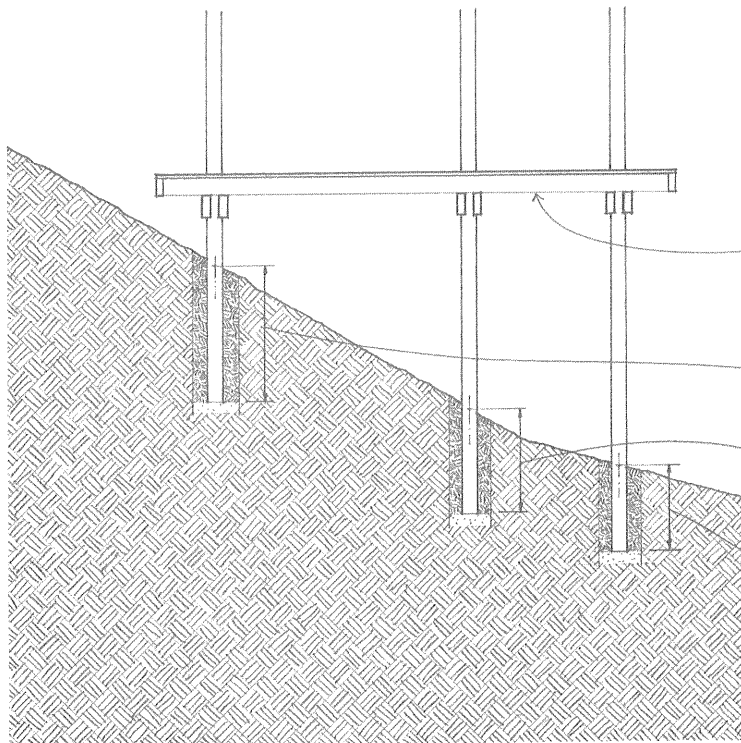


The treated poles are usually laid out along a grid defined by the beam-and-joint framing pattern. Their spacing determines both the beam-and-joint spans and the vertical loads they must support.

- 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 $\frac{1}{4}$ 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 m²)

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.

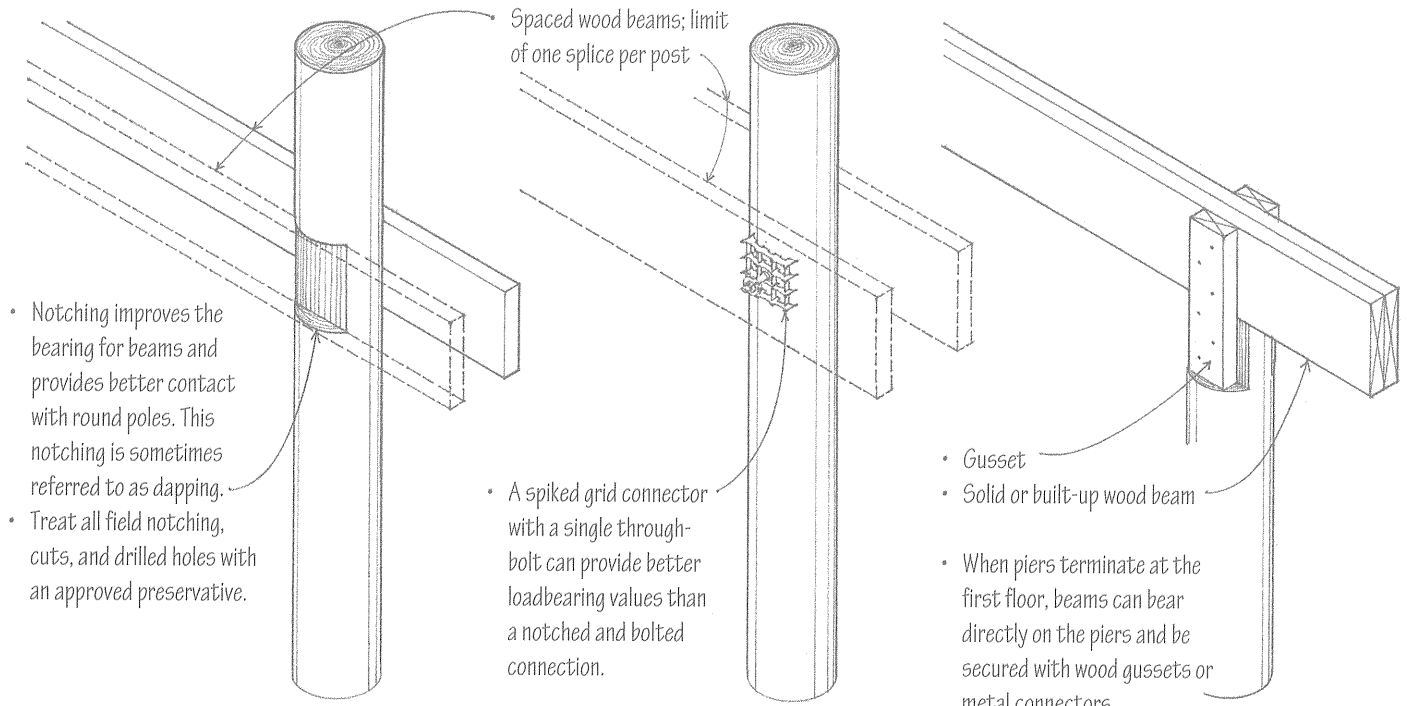
4' to 7' (1220 to 2135) for downhill poles

Embedment Length for Flat Slopes

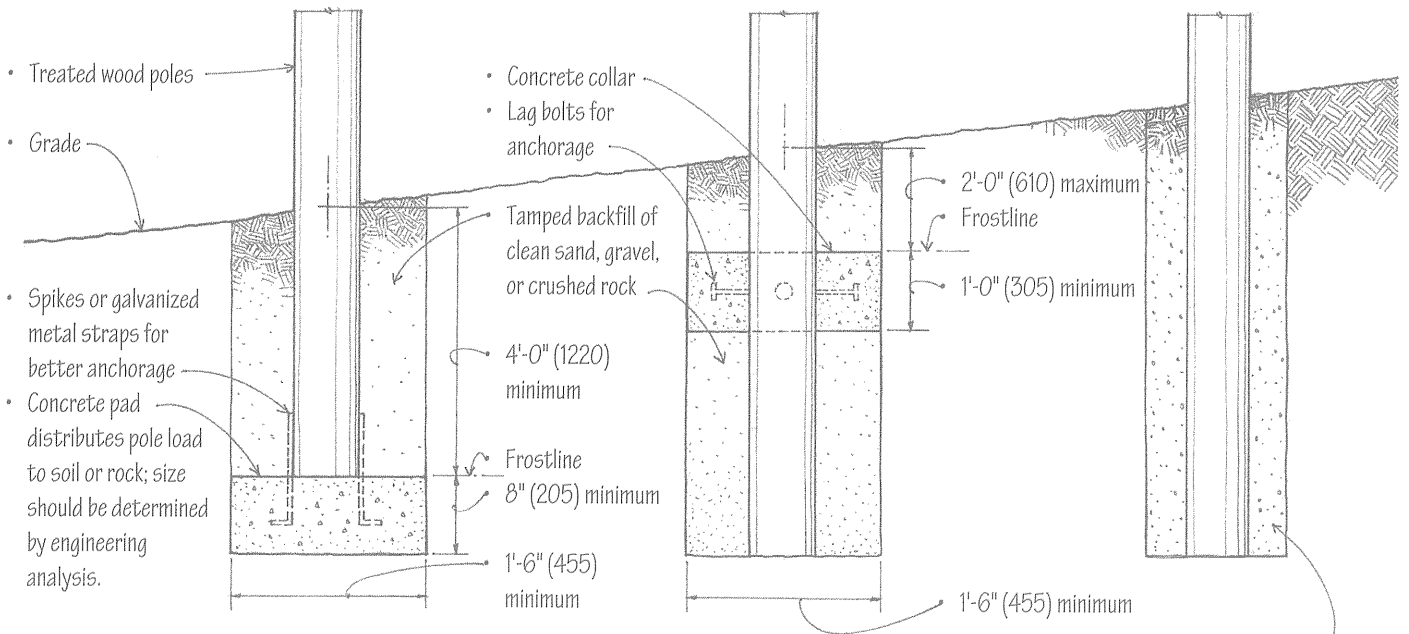
4' to 5' (1220 to 1525)

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.



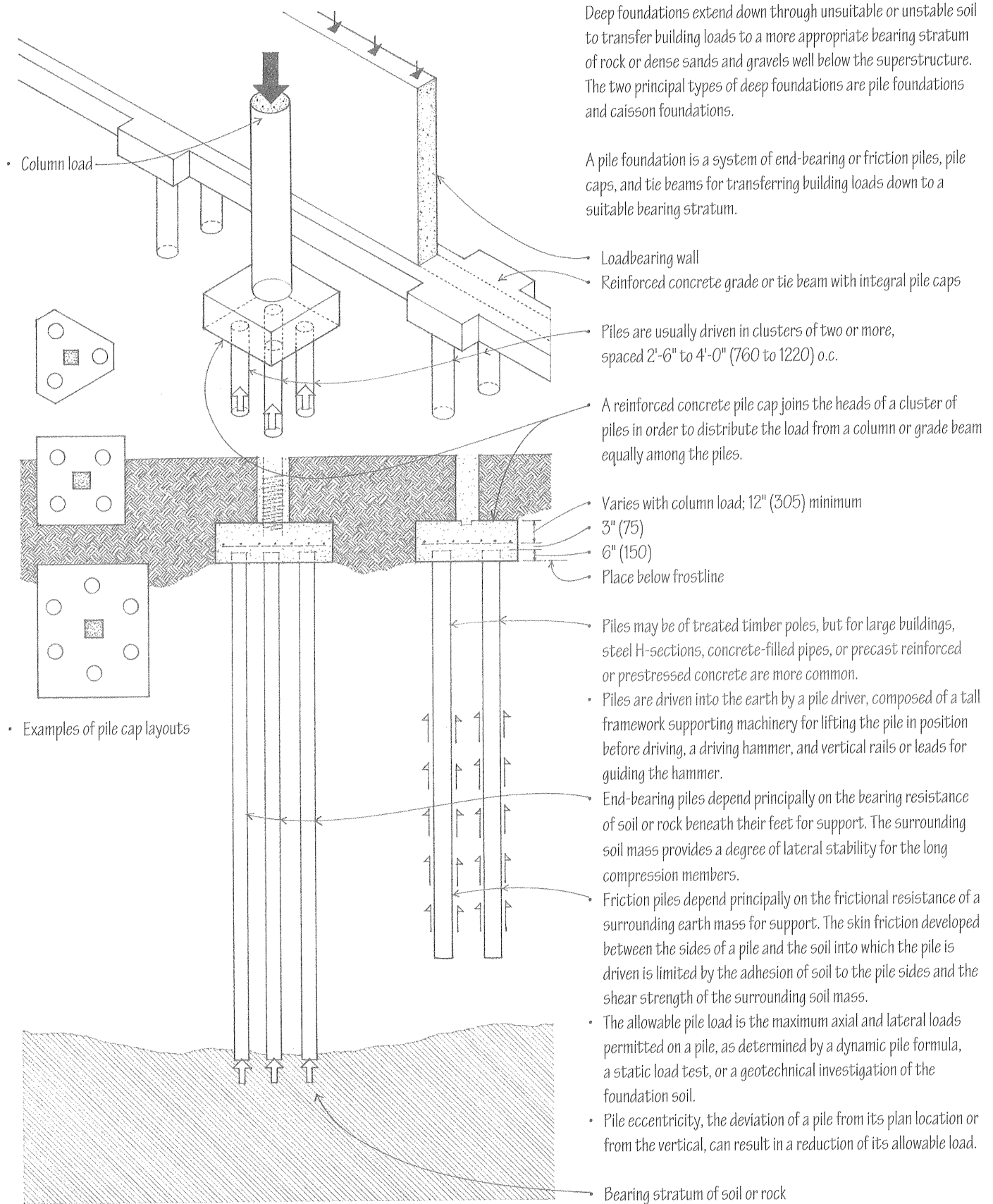
Spaced beams are through-bolted to the sides of the treated poles, which then continue up to form the loadbearing frame for the superstructure.



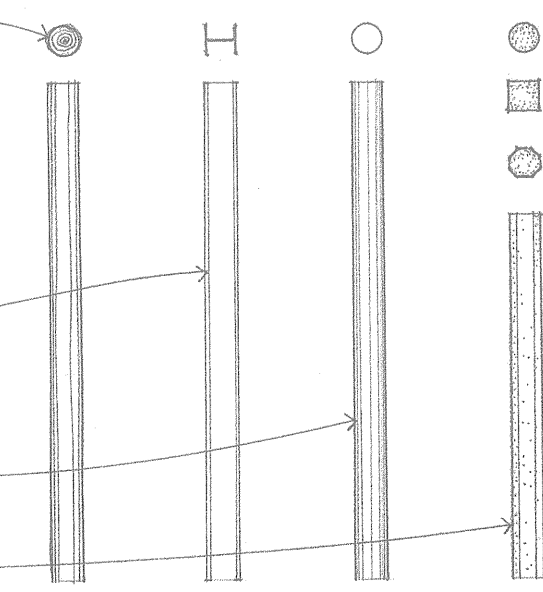
Poles may distribute their loads with a concrete footing or necklace or by bearing directly on rock. Concrete pads and collars increase the contact area of the poles with the soil and distribute their loads over a larger area.

- Backfilling with concrete or a soil-cement mixture can reduce the required embedment length; may be required on steep slopes with average or below-average soils.

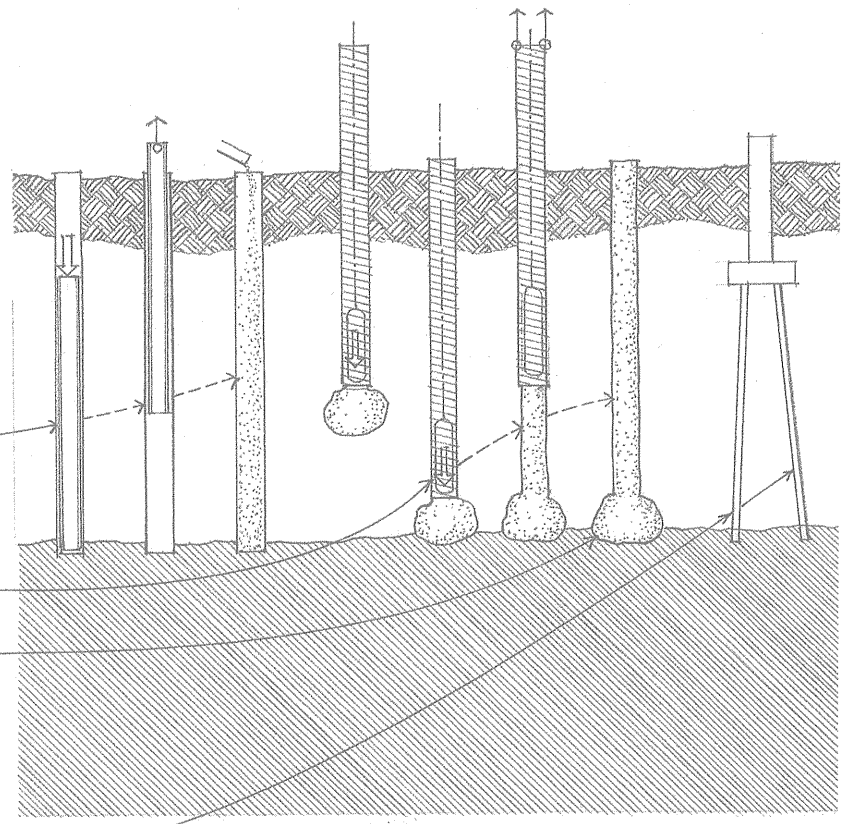
3.24 DEEP FOUNDATIONS



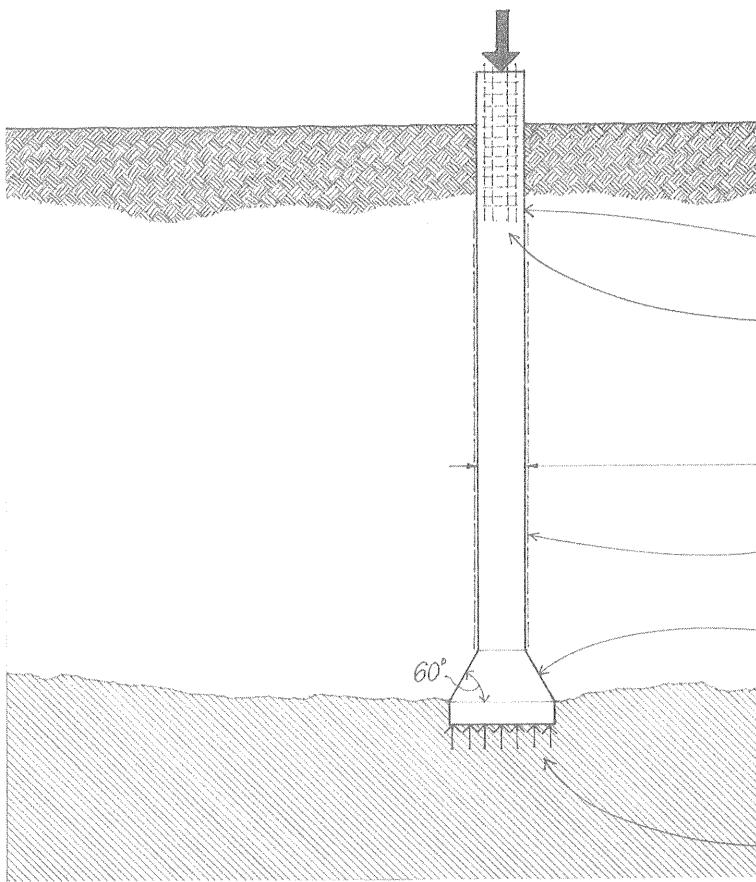
- Timber piles are logs driven usually as a friction pile. They are often fitted with a steel shoe and a drive band to prevent their shafts from splitting or shattering.
- Composite piles are constructed of two materials, such as a timber pile having a concrete upper section to prevent the portion of 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.



3.26 CAISSON FOUNDATIONS



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

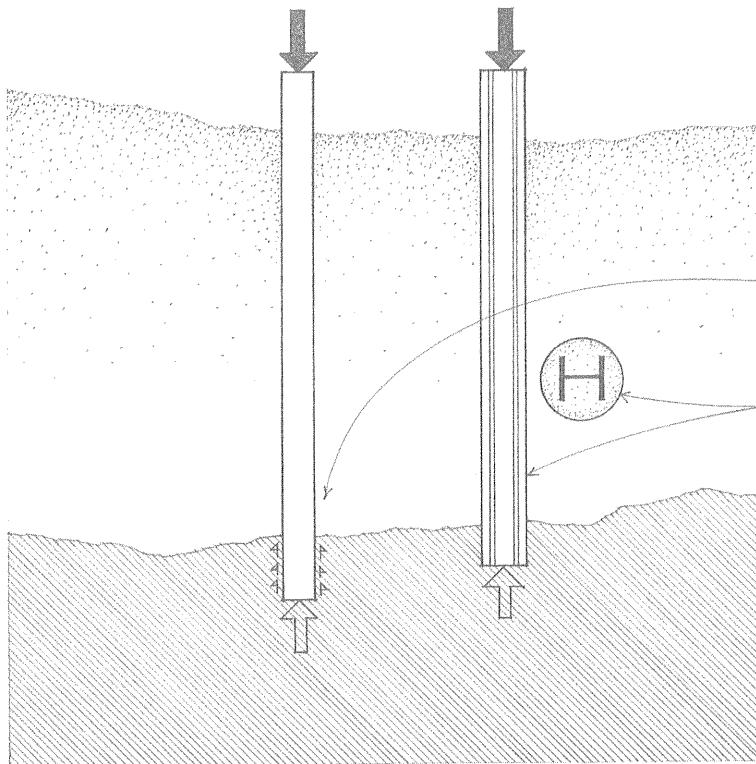
Reinforcement in upper part of shaft provides additional resistance to bending caused by lateral forces or eccentric column loading.

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.