Foundations
Soil and Building Support/Stresses

- **Bearing:**
  - Settlement: Uniform or Differential

- **Shear:**
  - Sloped Conditions
  - Non-Uniform Bearing
  - Earth Movement

- **Overturning**
  - Shifting Ground
  - Hydrostatic Pressure

- **Uplift**
  - Hydrostatic Pressure
Water

- **Surface Water** is water that runs along the ground as a result of rain, snow, downspout discharge, etc. Surface water problems are generally prevented through proper site grading.

- **Groundwater** is subsurface water whose level (the water table) fluctuates. Problems associated with groundwater include water table rise and capillary rise. Solutions to these problems include the following:
  - **Dewatering** - The removal of water from open excavation sites through the use of well points and pumps.
  - **Vapor Retarders** - Plastic membranes, which prevent water vapor from seeping into slabs on grade.
  - **Subdrainage Systems** - Foundation drains and underslab drains employed to direct water away from footings and slabs.
Subdrainage – Slabs and Perimeter Walls

Figure 2.57

Three methods of relieving water pressure around a building substructure. The gravel drain (left) is the standard method, but it is hard to do well because of the difficulty of separating the crushed stone and backfill soil in nearly separated, alternating layers. The drainage mat or drainage panel (right) is much easier and often more economical to install. It is a manufactured component that may be made of a loose mat of inert fibers, a plastic egg-crate structure, or some other very open, porous material. It is installed on the outside with a filter fabric that prevents fine soil particles from entering and clogging the drainage passages in the mat or panel. Water approaching the wall falls through the porous material to the drain pipe at the footing.

Below—Slab Drainage

Perforated pipe in crushed stone
Sump and pump

Above—Slab Drainage

Perforated pipe in crushed stone
Sump and pump
Foundation mat

Finish grade
Bituminous saturated felt or filter fabric
Pea gravel or sand
Vapor retarder
Drainage fill
Parging
Foundation drain
Earthwork

Earthwork is a broad category including all work associated with modification to the ground during construction. Earthwork operations include:

- **Grading** – Earthwork involving the sloping or contouring of the ground to prevent surface water from collecting under slabs or foundations. This generally involves sloping the ground away from built structure.

- **Rough Grading** - The addition or removal of earth prior to the start of construction.

- **Finish Grading** - The final distribution of earth at the conclusion of construction. Finish Grading takes into account the control of rain water as well as desired landscaping, walkways, roads, paved surfaces, and so forth.

- **Excavation** – The digging and removal of subsurface material down to the level required for new footings, foundations, etc.

- **Backfill** – Backfill is the re-placement of soil taken from an area within the same construction site. Backfill material should be deposited in layers of 6 to 12 inches in depth and should be thoroughly tamped and compacted to avoid settlement.

- **Cut and Fill** – Earthwork operation required where a building shape or location on a sloping side requires the relocation of existing soil on one area of the site to a different location. The term “cut” refers to the soil removed while the term “fill” refers to the replacement of the cut material.
Excavation Support Systems

• Structural systems put into place in order to protect and maintain the sidewalls within an excavated site are referred to as excavation support systems.

• Examples of Excavation support systems include the following:
  – *Ground stepping* - Sloping the sides of an excavation pit as a means of supporting the adjacent soil.
  – *Sheet Piling (or Sheeting)* - Temporary retaining walls of wood, metal, or precast concrete used to brace the weight of the adjacent soil. Sheet piling is composed of interlocking sections that are driven into the ground before excavation begins.
  – *Shoring and Bracing:* Structural bracing used in conjunction with sheet piling where piling alone is not adequate to resist the force of the surrounding excavation walls. Examples of shoring and bracing include:
    - **- Rakers**
    - **- Cross bracing**
    - **- Tie-backs**
  – *Underpinning* – The process of adding additional support to existing footings.
  – *Slurry Walls* – A type of sheeting in which a narrow trench is filled with a soupy mixture known as slurry. Reinforcing steel is then lowered into the trench. At this point, concrete is pumped in from the bottom of the trench as the slurry is pumped out. As the site is excavated, the foundation wall is tied back to the surrounding soil.
  – *Slope Protection and Erosion Control* – Earthwork involving the protection of exposed earth on a construction site. Protective measures include the use of diversion ditches, filter fabrics, and riprap.
Excavation – Sheeting & Shoring

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 gravel drains by horizontal steel crossbeams or by diagonal steel timber bearing on haul blocks or footings.
Concrete Foundation Systems

- A building’s foundation system forms its substructure, which supports its superstructure.

- The foundation system:
  - supports superstructure weight
  - resists horizontal or lateral loads from the adjacent ground
  - pressure from water in the soil known as hydrostatic pressure.
  - A building’s foundation system must distribute building loads so that settlement will be negligible or uniform under all parts of the building to keep the building structurally sound over its lifetime.

- There are two general types of foundation systems: shallow foundations and deep foundations.
Foundations – Loads, Reinforcement

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 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

Steel Column

A steel base plate necessary to all column load on enough that the stresses in the post exceed.

See 5.50 for all connections.
Shallow Foundations

- If the soils close to the ground are adequate to support the required building loads, the most economical system is shallow spread footings. A footing is an enlarged, usually concrete, base that distributes the load directly to the underlying soil. Footings must sit beneath the frost line on firm soil that allows for proper drainage. Footings may be continuous footings, stepped footings, or isolated footings. Other types of footings include:

  - Combined footing – A footing located at a property line that is connected to the first interior column footing.

  - Cantilever footing – An eccentrically loaded footing located at a property line.

  - Mat footing or Raft Foundation – One large footing that extends beneath the entire building to distribute the load over a large area where the soil bearing capacity is low.

  - Boat or Floating footing – Similar to a mat footing except that it is placed at a depth such that the weight of the displaced soil equals the total weight of the new structure.
Shallow Foundations - Types

- Perimeter Wall Foundation (Wall Footing, Strip Footing)
- Combined Footing
- Cantilever Footing
- Floating Foundation
Shallow Foundations – Sloped Site

Stepped Foundation

Pole Foundation
Shallow Foundations

Light Construction – Residential Perimeter Wall Foundation
(Wall Footing, Strip Footing)
Concrete Slab on Grade

- 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.

Thickened Edge Slab

- 6" (150) minimum clear distance from any wood to finish grade
- 12" (305) minimum footing depth
- Set below frostline.

- 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.

Underpinning
Deep Foundations

A deep foundation is required where the upper soils have insufficient bearing capacity to support spread footings. In such cases, the load is transferred through the inadequate soil to deeper layers of soil or rock with greater strength. Examples of deep foundations include the following:

- **Piles** – Piles are column-like structural elements hammer driven through poor soil to lower levels of soil with greater bearing capacity. The weight of a building’s structure is transferred to a widened concrete section called a *pile cap*, which in turn sits on the piles.

- Pile foundations are of two types: *point bearing piles*, and *friction piles*. Piles may be made of wood, concrete, steel, or a combination of these. Piles are capable of carrying anywhere from 40 tons (for wood piles) up to 500 tons (for prestressed concrete cylinders).

- **Caissons** – Caissons are vertical point bearing structures set into the ground and then filled with concrete. They extend through weak soil down to firm soil or bedrock. Caissons can carry more than 3500 tons.

- **Cofferdams** – Utilized in bridge supports, or in similar cases where the removal of water is required. Watertight sheet piling is put into place, the water is pumped out and the foundation is then constructed.
Deep Foundations