FOUNDATIONS

FOUNDATIONS - OVERVIEW

- **Loads and settlements of foundations - Safe foundations**
- **Types of soils that make up the foundation - Properties**
- **Properties of foundations: Strength, Stability, Drainage, etc. - Estimating soil properties: Exploration and testing**
- **Construction of foundations - Type of soil layers at the top, excavation, support for soil, soil strengthening, de-watering**
- **Types of foundations - Shallow and deep - Influence zone**
- **Precautions - Seismic base isolation; Underpinning during construction; Retaining walls; Waterproofing, drainage, reinforcing & insulation; Frost protection**
- **Foundation design for optimal cost**

INTRODUCTION TO FOUNDATIONS

- Function of a foundation is to transfer the structural loads from a building safely into the ground. A backyard tool shed may need only wooden skids to spread its load across an area of ground surface, whereas a house would need greater stability and consequently its foundation should reach the underlying soil that is free of organic matter and unreachable by the winter's frost. A larger and heavier building of masonry, steel, or concrete would require its foundations to go deeper into earth such that the soil or the rock on which it is founded is competent to carry its massive loads; on some sites, this means going a hundred feet or more below the surface. Because of the variety of soil, rock, and water conditions that are encountered below the surface of the ground and the unique demands that many buildings make upon the foundations, foundation design is a highly specialized field of geotechnical engineering.

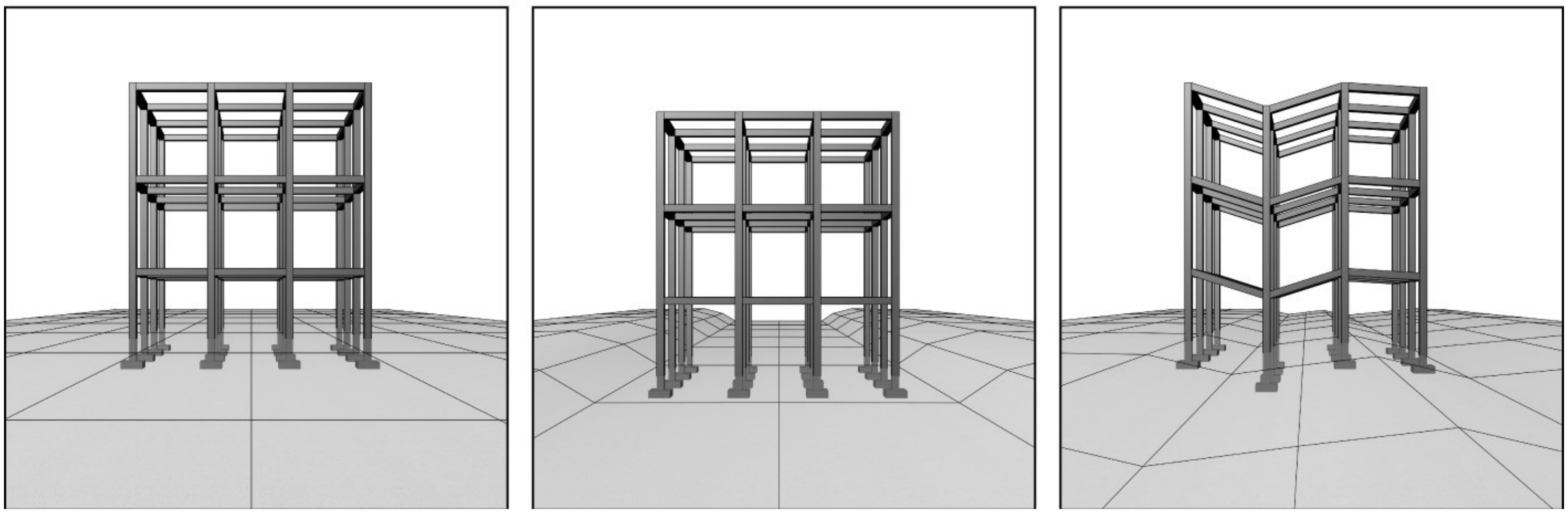
2.3 LOAD AND SETTLEMENTS OF FOUNDATIONS

- **Types of loads on foundations:** Dead, live, wind, inclined thrusts and uplift, water table and earthquake forces
- **Types of settlements:** Uniform and differential - Differential settlement must be minimized, depends on site soil conditions and distribution of loads on columns supporting the building
- **Requirements of a safe foundation:** Structure-foundation system safe against settlements that would lead to collapse - Foundation settlement should not damage the structure - Foundation must be technically and economically feasible

Foundation Loads

- Dead Load
- Live Load
- Wind Load
- Horizontal Pressures Below Grade
- Structural Member Forces
- Uplift
- Earthquake

SETTLEMENTS OF FOUNDATIONS



NO SETTLEMENT * TOTAL SETTLEMENT * DIFFERENTIAL SETTLEMENT

Uniform settlement is usually of little consequence in a building, but differential settlement can cause severe structural damage

2.4 TYPES OF SOILS AND CHARACTERISTICS

- **Rocks and soils** - Rocks: Broken into regular and irregular sizes by joints - **Soils** (particulate earth material): **Boulder** (too large to be lifted by hands), **cobble** (particle that can be lifted by a single hand), **gravel aggregates** (course grained particle larger than 6.4mm) , **sand** (frictional, size varies from 6.4 to 0.06mm), **silts** (frictional, low surface-area to volume ratio, size varies from 0.06 mm to 0.002mm) **and clays** (cohesive - fine grained - high surface-area to volume ratio, size smaller than 0.002 mm) - **Peat** (soils not suitable for foundations) - In USA classified according to **Unified Soil Classification System**


Porous (sandy)
Clays

2.5 PROPERTIES OF FOUNDATION

- **Strength:** Load bearing capacities: Crystalline rocks (very strong - 12,000 psf), sedimentary rocks (intermediate - 6,000 psf) and other types of soils (relatively lower - 2,000 to 3,000 psf)
- **Stable under loads** (creep, shrinkage and swelling)
- **Drainage characteristics:** Porosity and permeability
- **Soil property estimation:** Subsurface exploration (test pits - less than 8 ft in depth; borings - greater than 8 ft) - Estimate level of water table - Testing of soil sample in laboratory for various properties: Particle size distribution, Liquid limit, Plastic limit, Water content, Permeability, Shrinkage/ swelling, Shear/compressive strength, Consolidation (creep and settlement)

2.6 CONSTRUCTION OF FOUNDATIONS

- Some amount of **excavation** required for every building - Top soil consisting of organic matter is removed - **Below the region of soil erosion (by water and wind) & below the level of permafrost** - To the required depth at which the bearing capacity necessary for the building is met - **A variety of machines used for excavation** - The sides of excavation too be protected from caving in by **benching, sheeting** (soldier beams and lagging, sheet piles, slurry walls, etc.) **or bracing** (cross-slot, rakers or tiebacks) - **De-watering** using **well-points & sumps, and watertight barriers** - **Mixing the soil** by rotating paddles
- Bulldozers * Shovel dozers * Back hoes
- Bucket loaders * Scrapers * Trenching machines
- Power shovels * Tractor-mounted rippers * Pneumatic hammers
- Drop balls * Hydraulic splitters * Blasting

DOZERS

Backhoe

Unrestricted Site

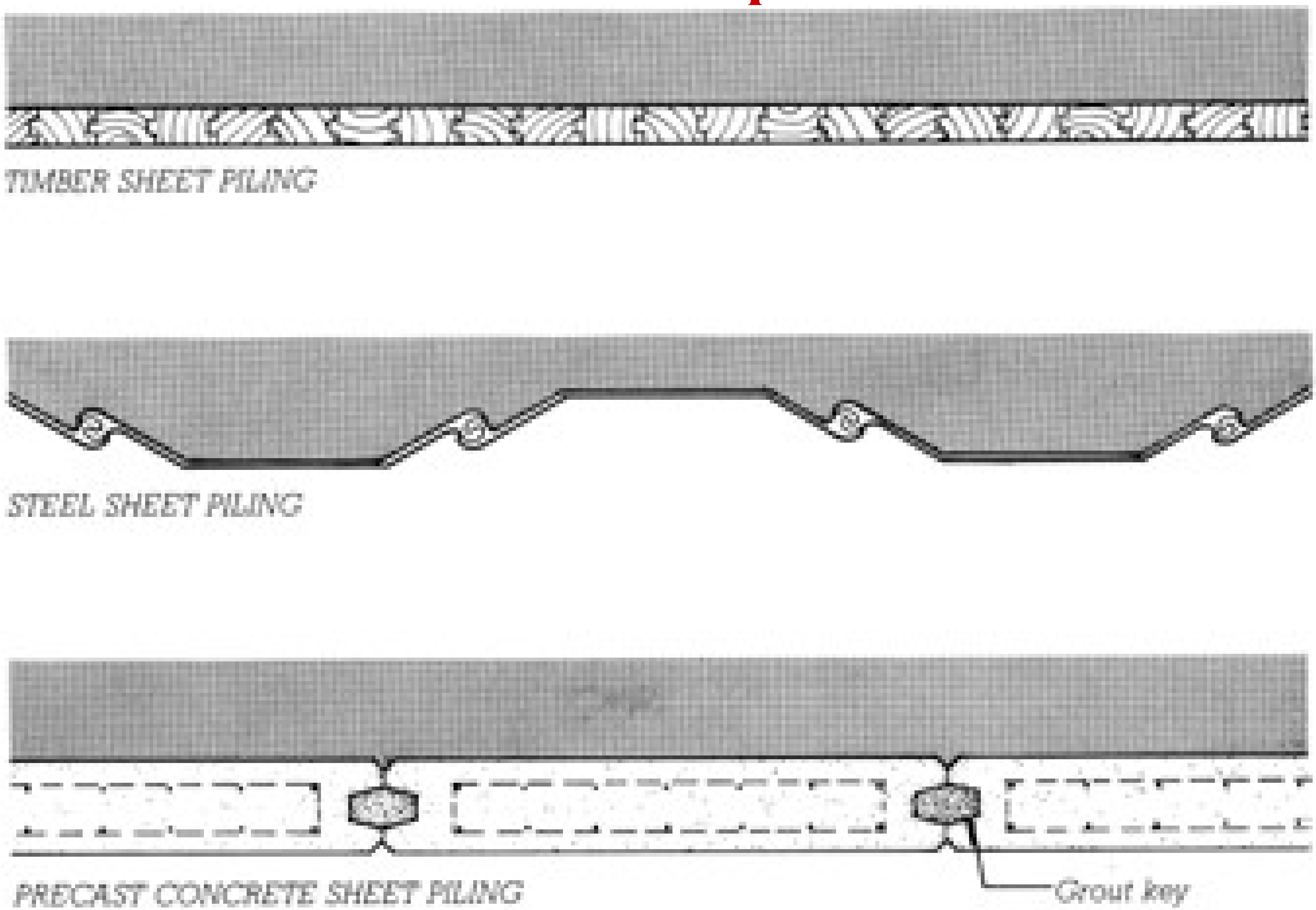
Bench and/or Angle of Repose
Must have perimeter clearance
Considerations
- Bank Erosion
- Water Diversion
- Safety
- Storage of Backfill (& cost)

Most likely - least expensive

Benched Excavation

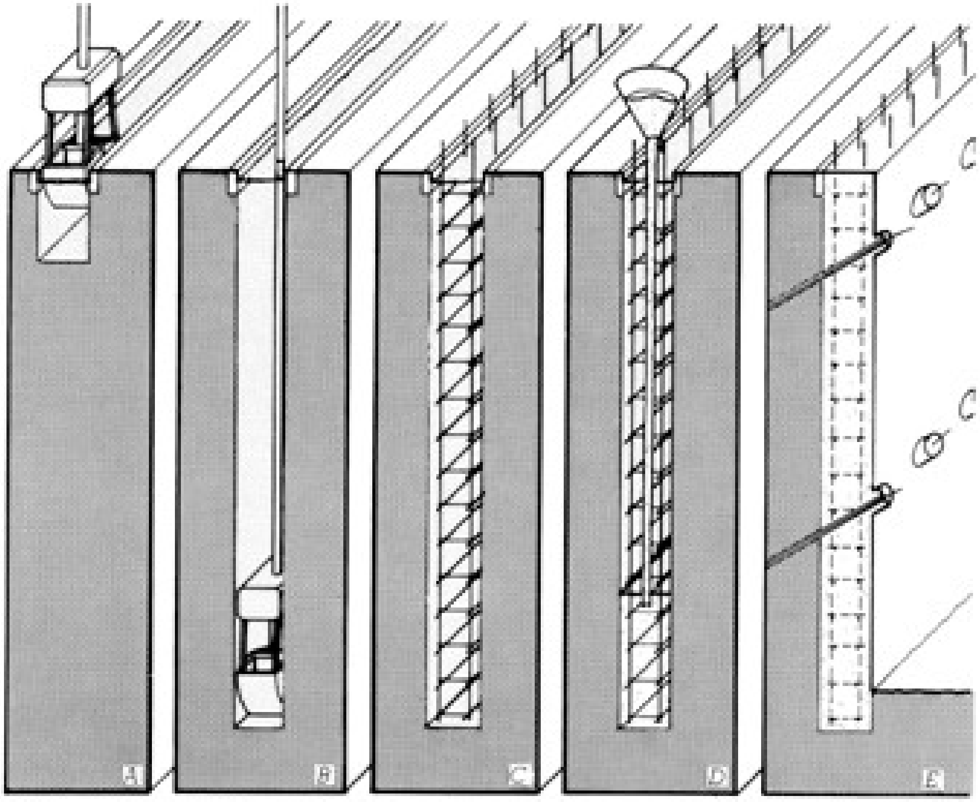
Solder Beam & Lagging

Sheet Pile Options



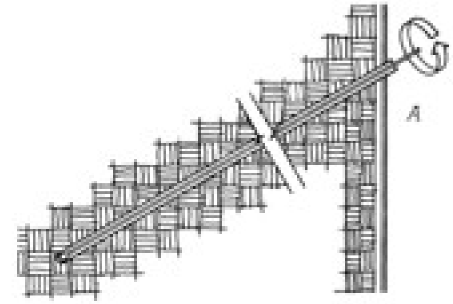
Slurry Wall

- **Steps**
  - ➔Layout
  - ➔Excavate the soil
  - ➔Interject Slurry to prevent Collapse as Excavation Continues
  - ➔Install Reinforcing
  - ➔Place Concrete (replaces the slurry mix)

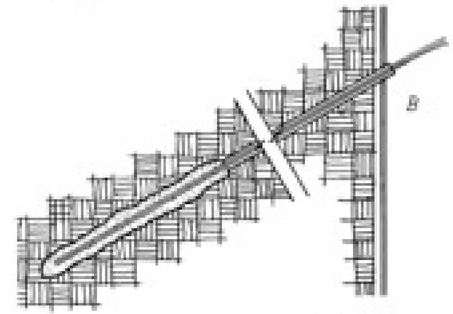


Tieback Installation

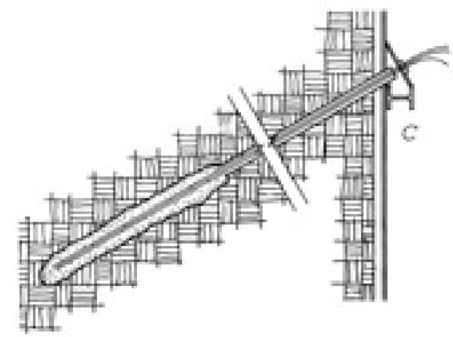
- Rotary Drill Hole



- Insert & Grout Tendons

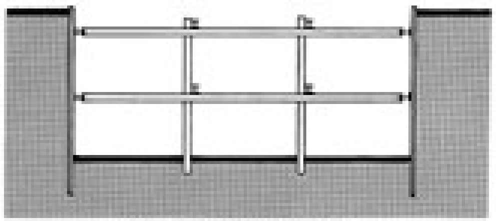


- Tendons Stressed & Anchored



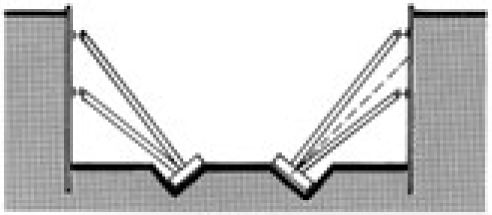
Bracing

- Crosslot



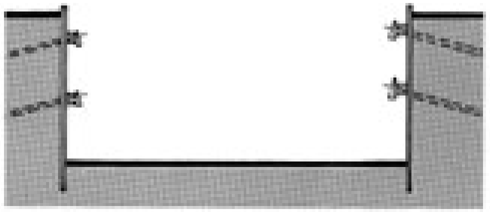
CROSSLOT BRACING

- Rackers



RAKERS

- Tiebacks



TIEBACKS

Bank Requiring a Retention System

Retention System Depends On:

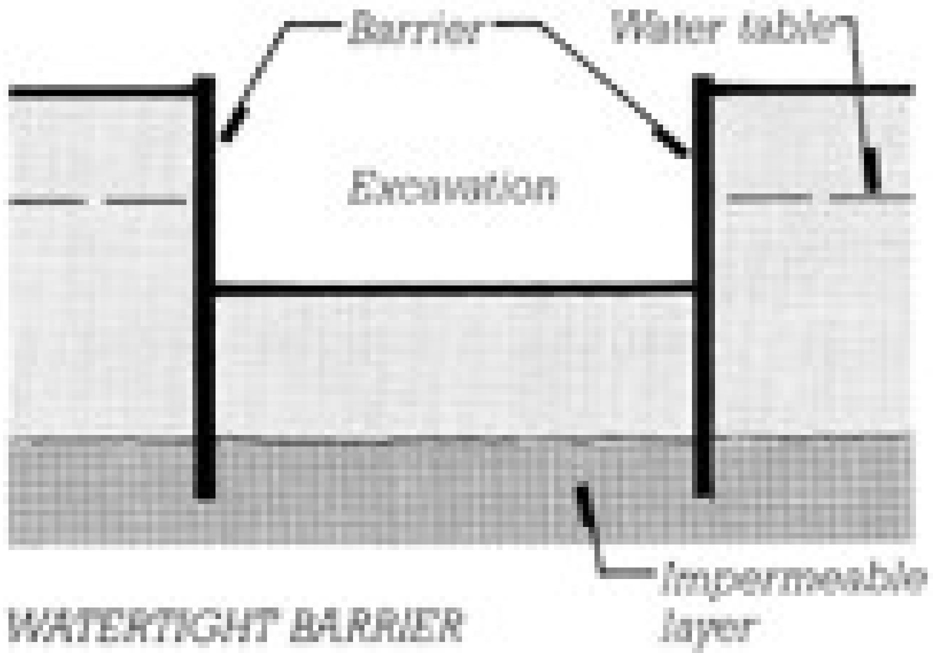
- Proximity to Buildings
- Type of Soil
- Water Table Level
- Temporary or Permanent
- Contractor Preference
- Cost - KEY Consideration

Dewatering

- A process of removing *Water* and/or lowering the *Water Table* within a construction site
- Purpose: To Provide a Dry working platform - (typically required by Code and Specification)
- If the Water Table is above the working platform;
  Options:
    - » Keep water out
    - » Let water in & remove it
    - » Combination

Watertight Barrier Walls

- Keep Water Out
- Barrier must reach an impervious strata
- Types
  - Slurry Walls
  - Sheeting w/ pumps
- Must resist hydrostatic pressure



2.7 TYPES OF FOUNDATION

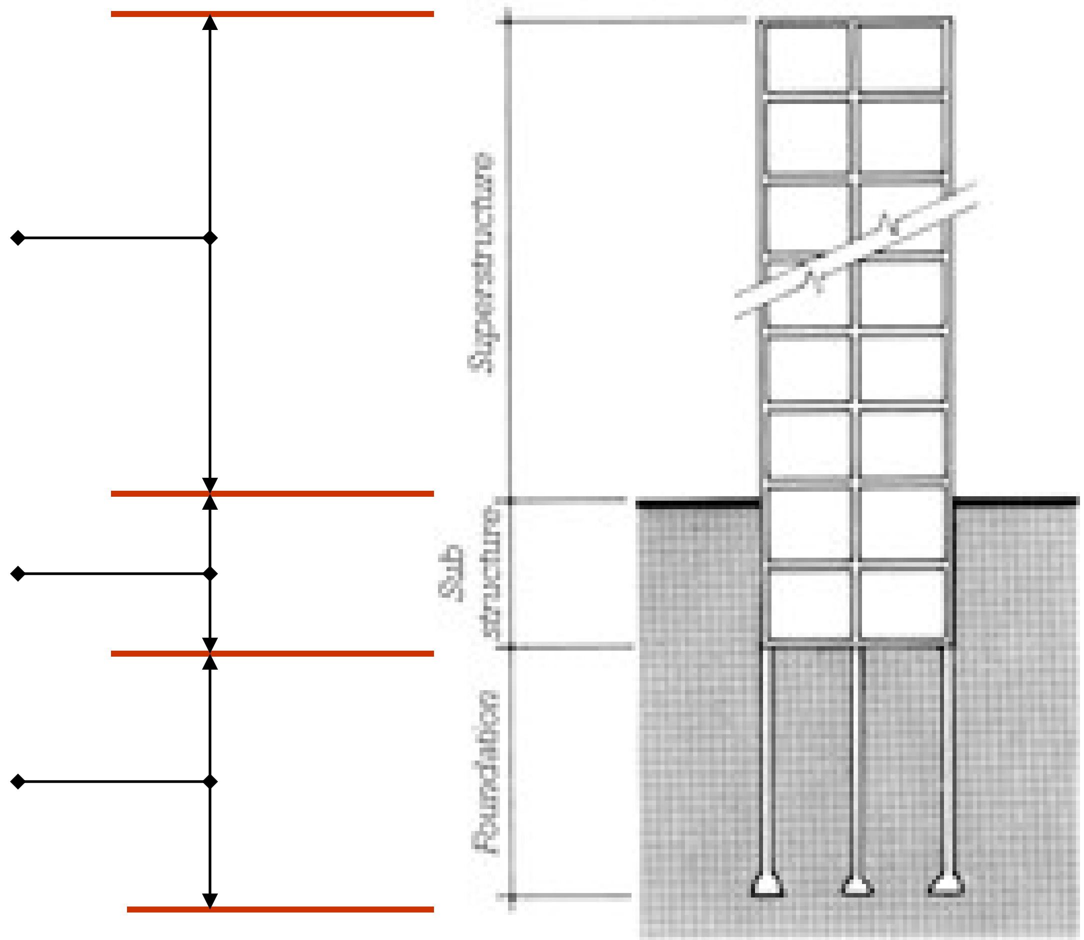
- A building consists of **superstructure, substructure and the foundations** - **Two types foundations : Shallow and Deep** - Depends on whether the **load transfer** is at deeper depths or shallower depths - Need for these two types (soil strength, ground water conditions, foundation loads, construction methods and impact on adjacent property) -**Shallow foundations** (column footings without or with tie/grade beams, individual or combined wall footing, slab on grade, raft) - **Deep foundations** (caissons with or without sockets, end bearing or friction piles, pile groups), zone of influence, made of concrete (regular or site-cast) or steel or wood

Major Building Parts

Superstructure

Substructure

Foundation



Primary Factors Affecting Foundation Choice

- Subsurface soil
- Ground water conditions
- Structural requirements

Secondary Factors Affecting Foundation Choice

- Construction access, methods & site conditions
- Environmental factors
- Building Codes & Regulations
- Impact on surrounding structures
- Construction schedule
- Construction risks

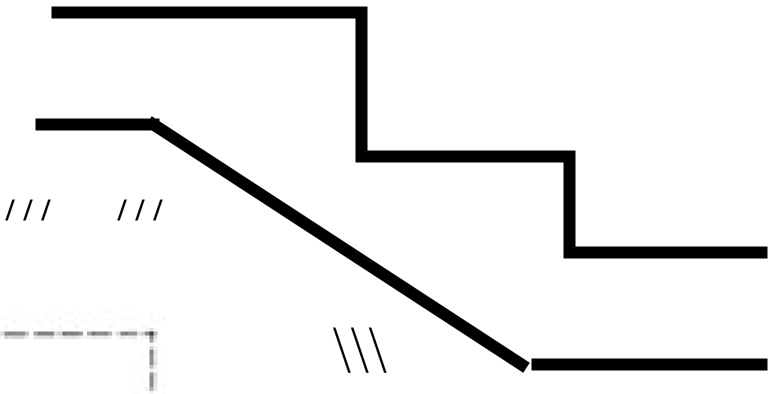
Shallow Foundations

- Requirements
  - Suitable soil bearing capacity
  - Undisturbed soil or engineered fill
- Basic types or configurations
  - Column footings
  - Wall or strip footings

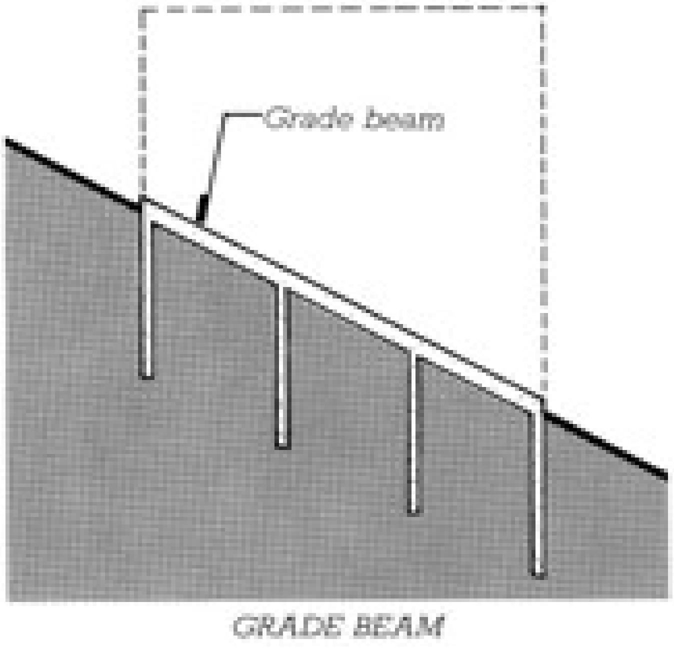

Combination Spread & Strip Footing

Shallow Foundations

Stepped strip footings

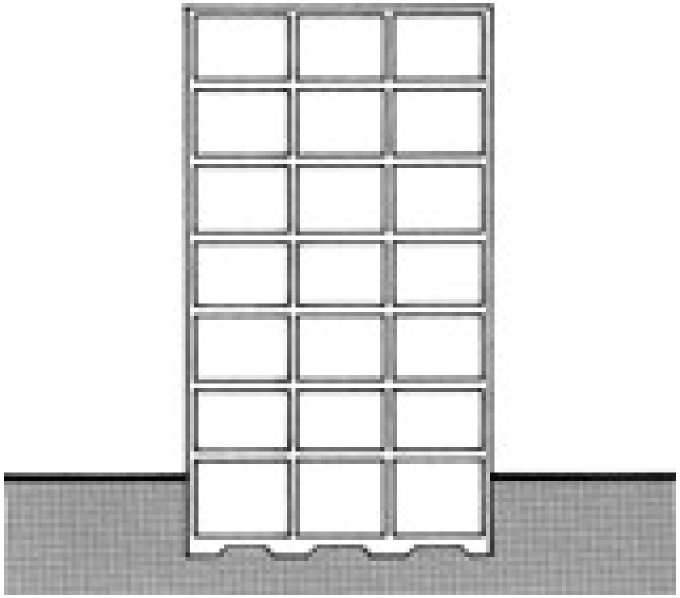


Grade Beams



Shallow Foundations

- SOG with thickened edges
- Eccentrically loaded footings
- Mat foundation
- Floating (Mat) foundation

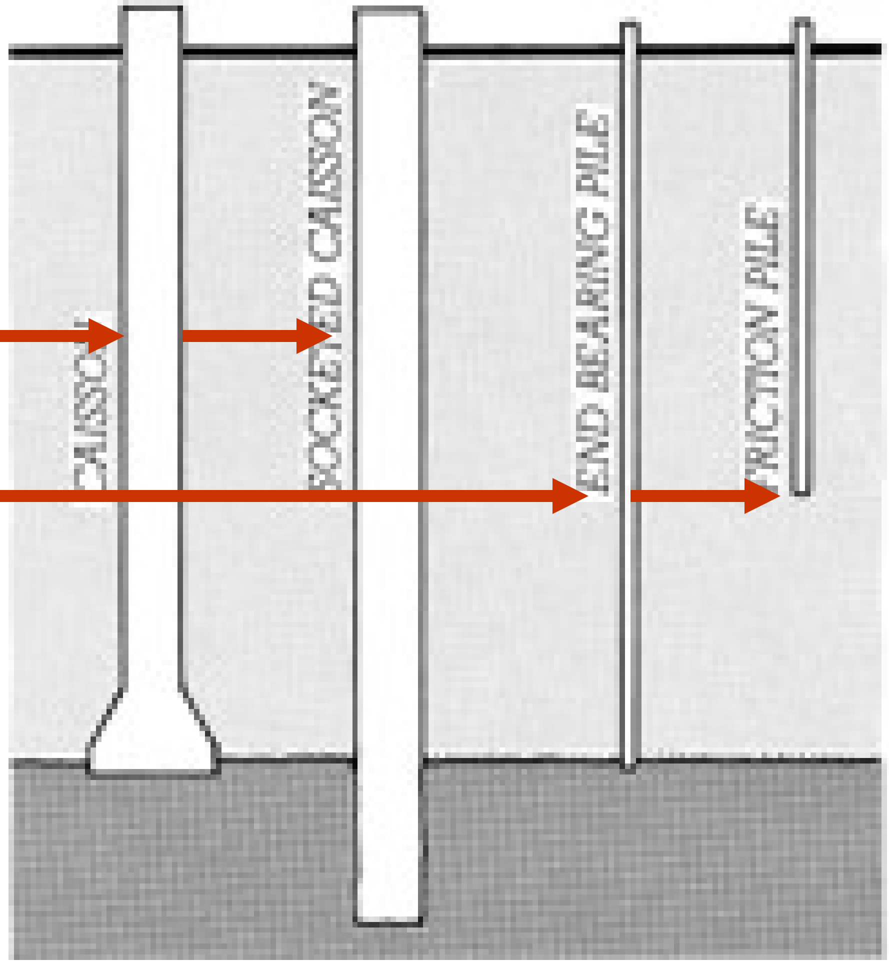


Deep Foundations - Purpose

transfer building loads deep into the earth

Basic types

- Drilled (& poured)
- Driven



Caisson Installation Sequence

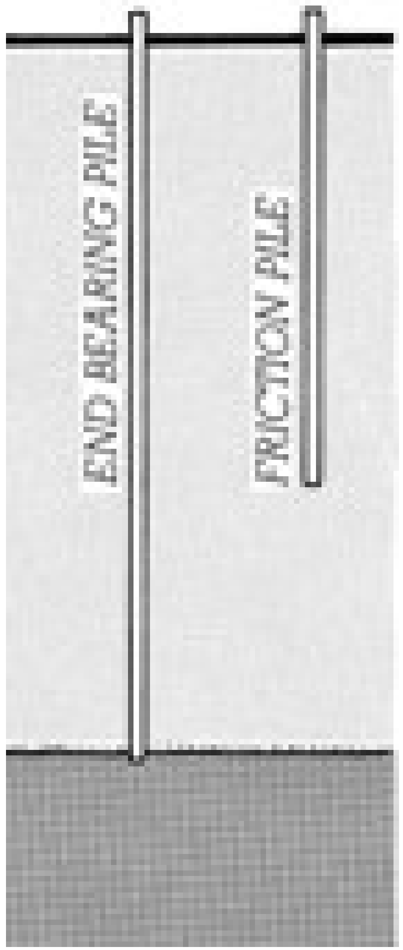
- Hole drilled with a large drill rig
- Casing installed (typically)
- Bell or Tip enlargement (optional)
- Bottom inspected and tested
- Reinforced
- Concrete placement (& casing removal)


D 7

Driven Piles

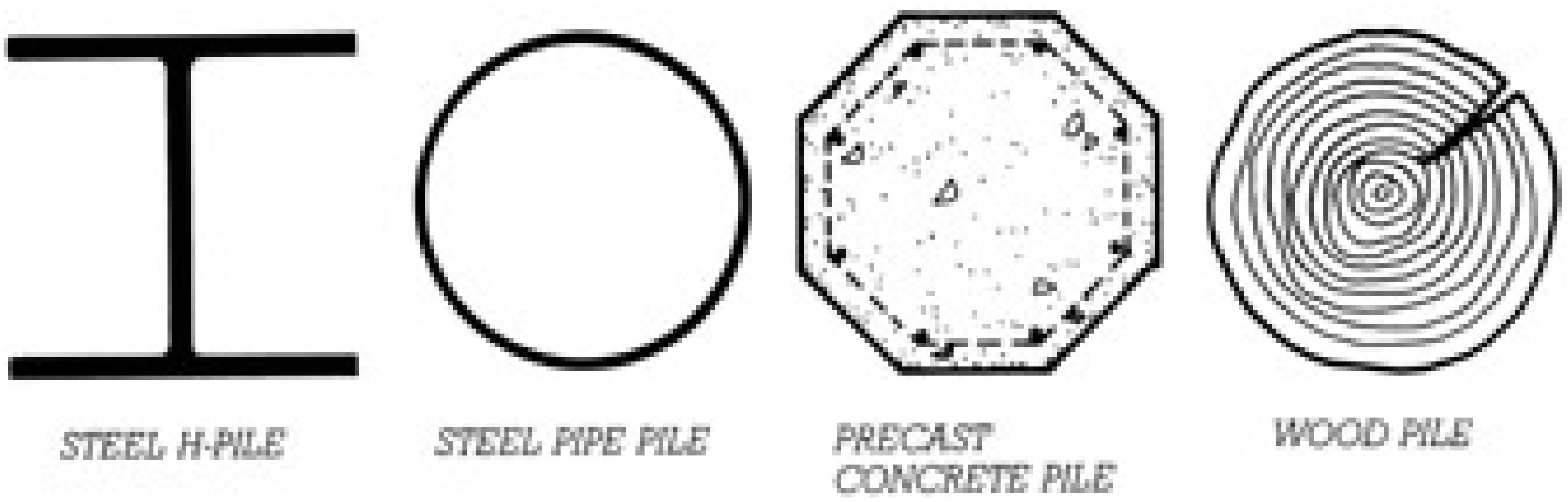
Two basic types of Piles

- **End bearing pile** - point loading
- **Friction pile** - load transferred by friction resistance between the pile and the earth



Pile material

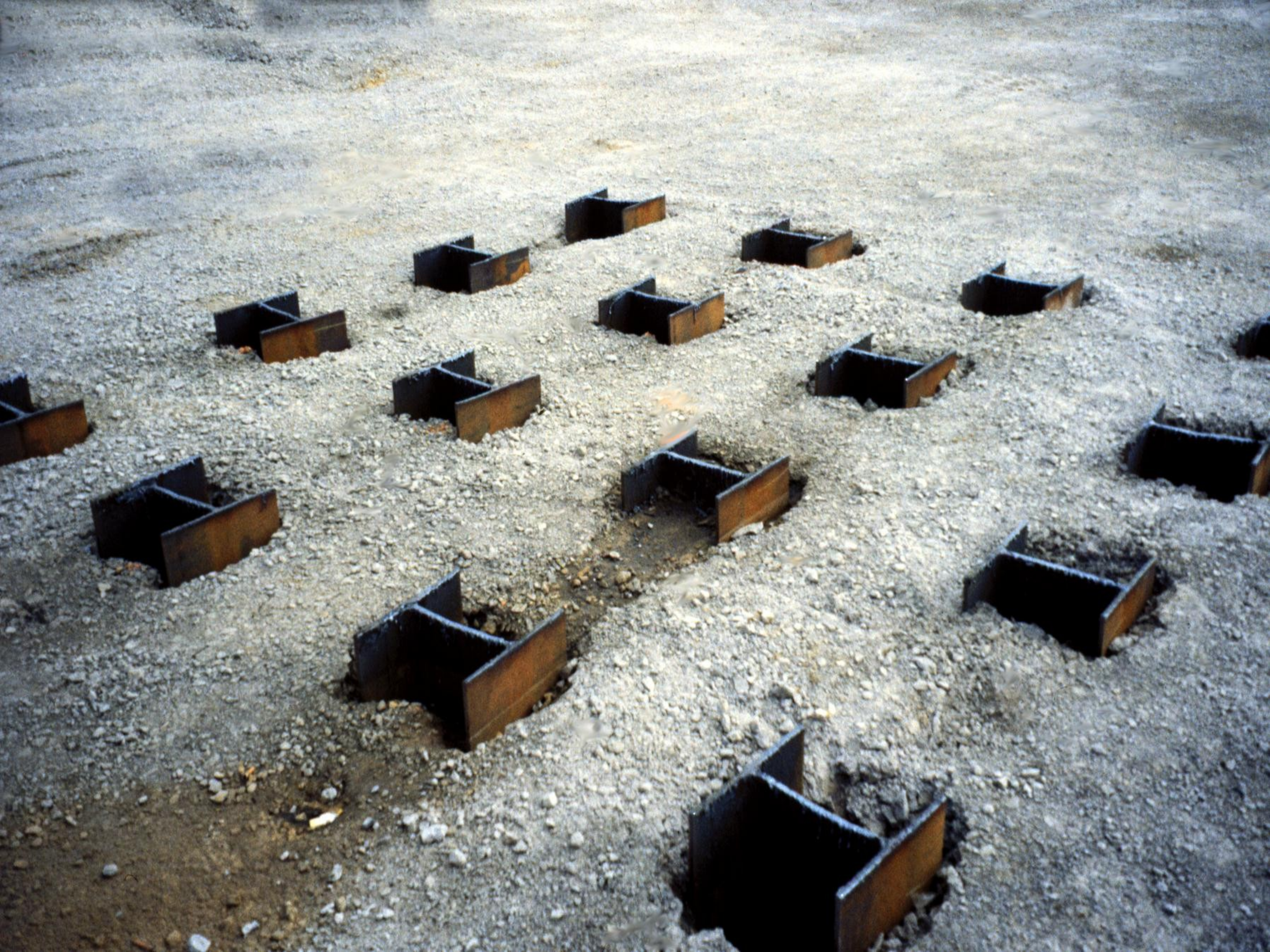
- Steel; H- piles, Steel pipe
- Concrete; Site cast or Precast
- Wood; Timber
- Composite



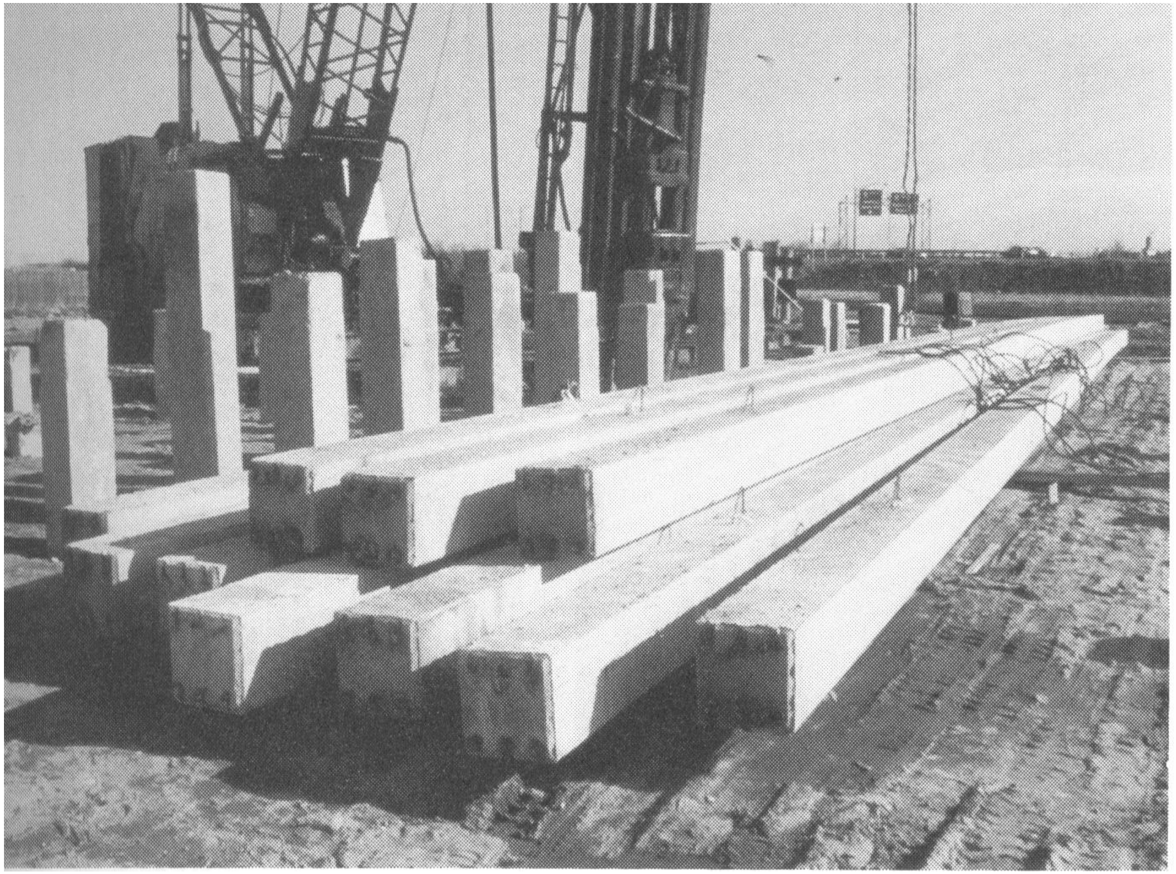
Driven Piles

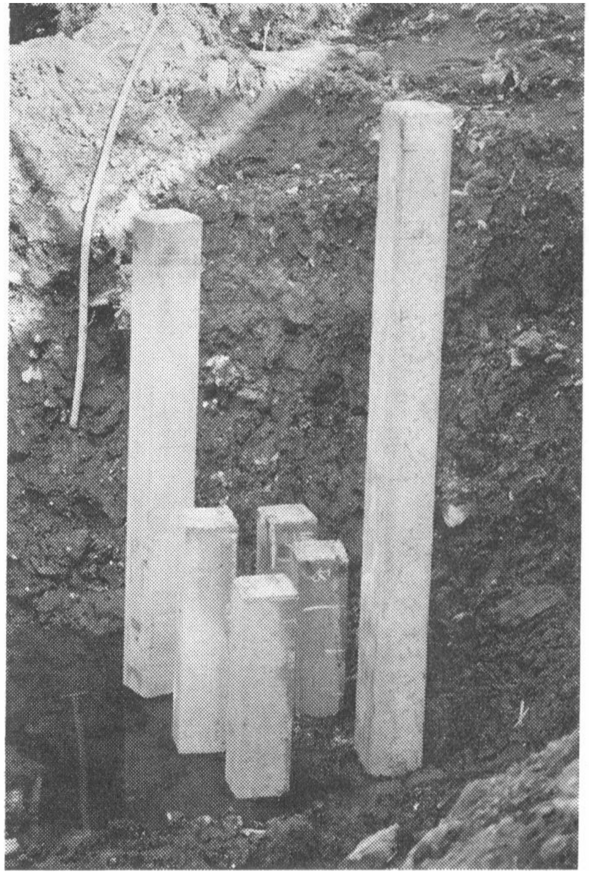
The following photo sequence was taken at the site of the:

- Nashville Coliseum
  - 67,000 seat sports coliseum in Nashville, TN
  - The Facility had *Deep Foundations*:
    - » 3,500 Driven Piles; 12x53 H Piles w/ End Bearing
    - » Pile length varied from 25’-75’
    - » Used 3 Pile Drivers w/ Diesel Powered Hammers
    - » Driving rate: 20-25 piles/day/rig
    - » Driving tolerance: 3”-6”



Precast Concrete Plies

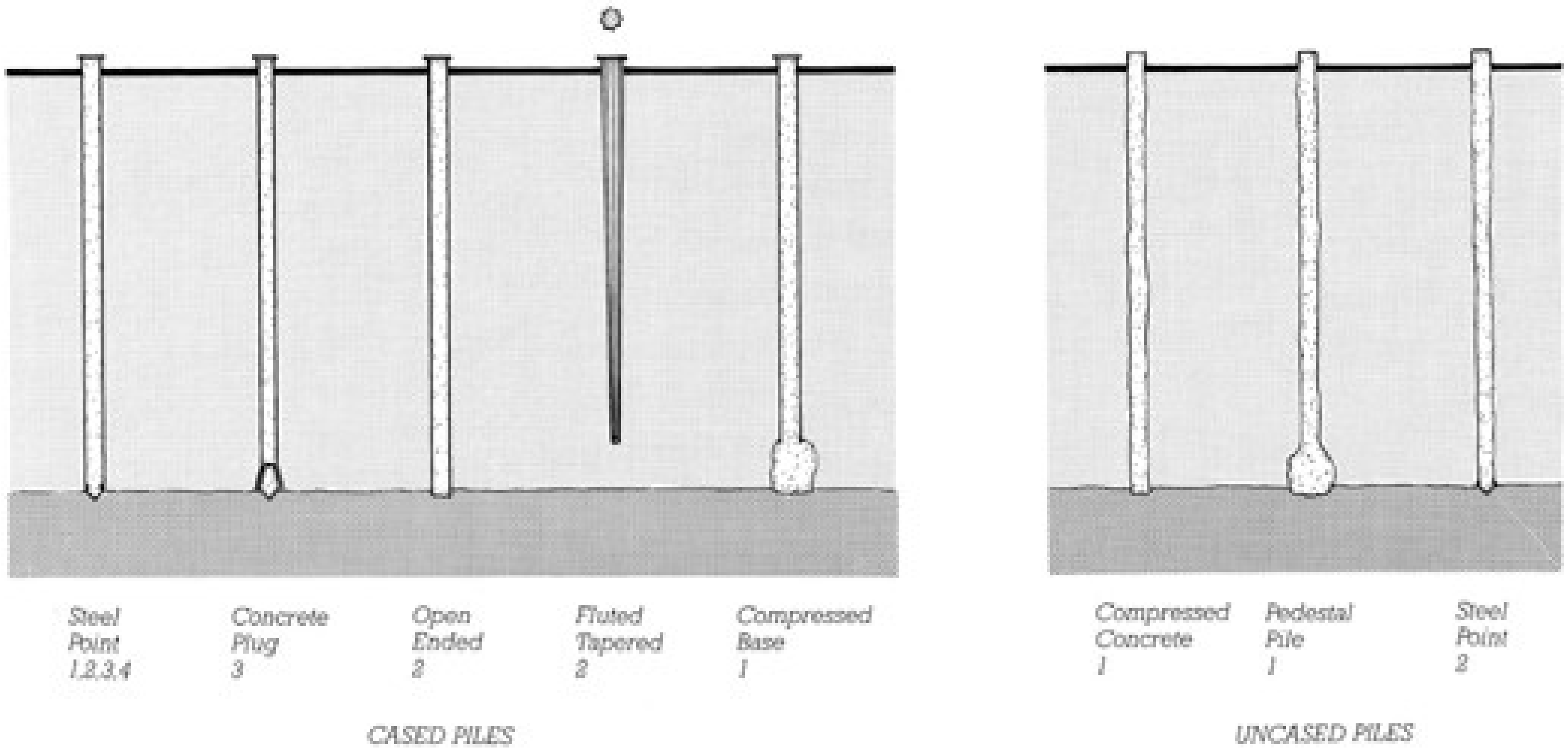




Site Cast Concrete Piles

Cased Piles

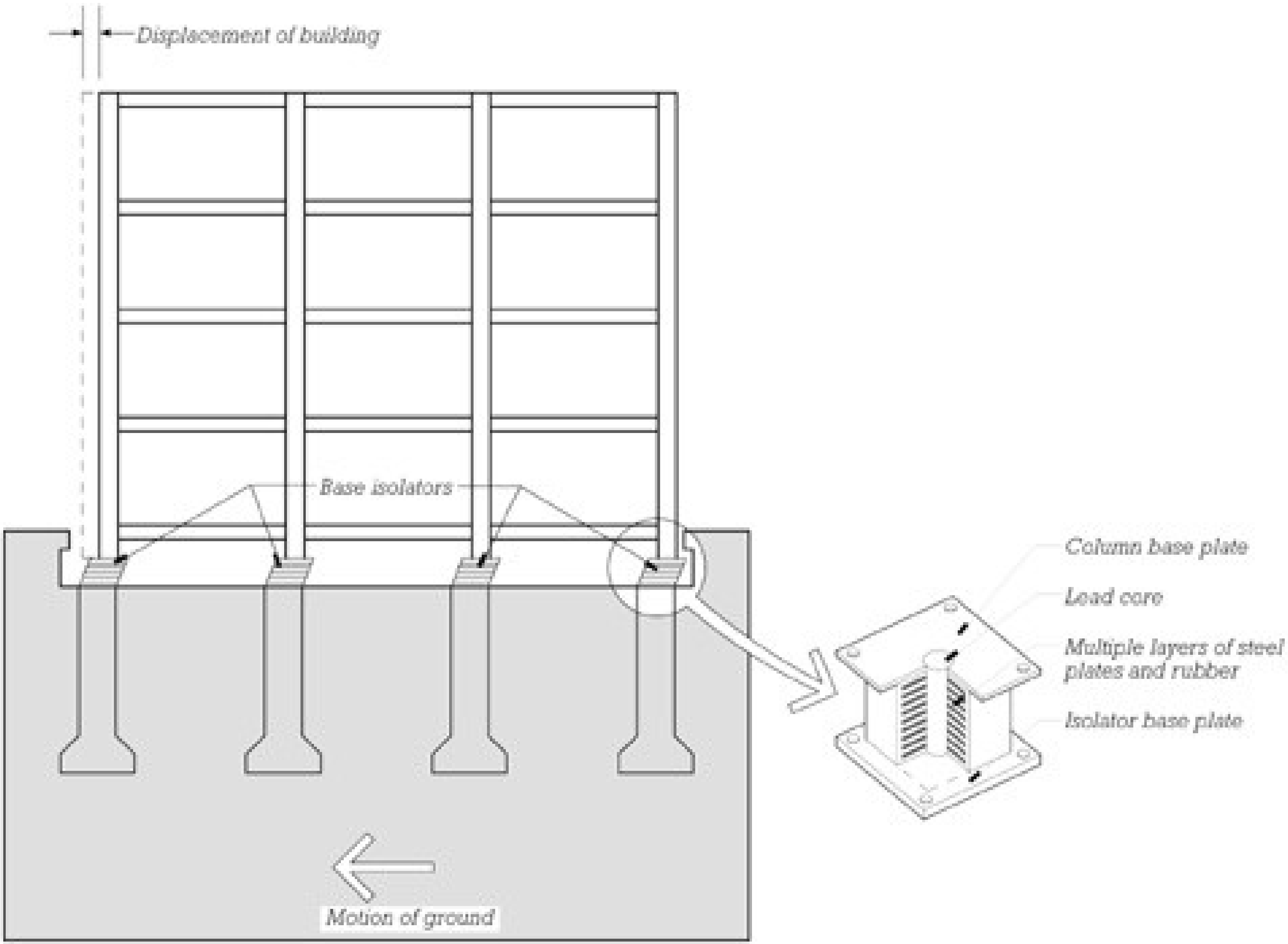
Uncased Piles



2.8 PRECAUTIONS TO BE TAKEN

- **Seismic base isolation** in seismic areas - **Underpinning** required to carry out repairs to the existing building or to add some changes in the foundations - **Retaining walls** to hold the soil back from caving in: **Types of failure such as overturning, sliding and undermining should be avoided**, non-reinforced or/and reinforced cantilevered retaining walls, drainage behind the wall to eliminate piping of water in soil - **Water proofing** (use waterproof membranes, asphalt coating) **and drainage** (perforated pipes) of foundations - **Basement insulation** (polystyrene or glass fiber boards placed on the outside or inside with drainage mats) - **Frost protection** through protective coatings and plastic foam insulation - **Back-filling with properly draining soils**

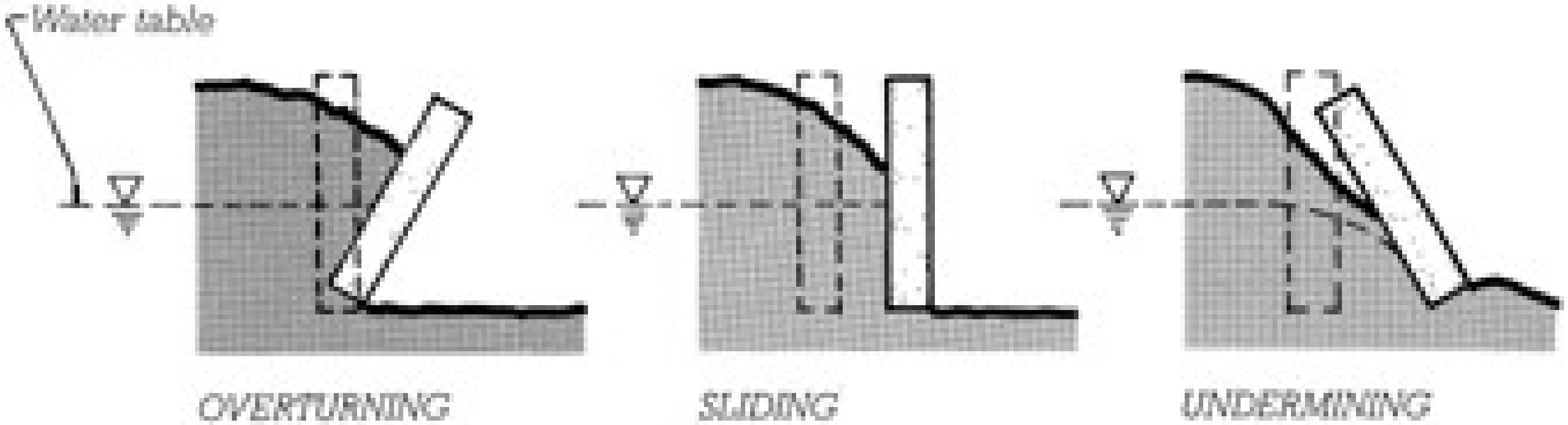
Seismic Base Isolation



Retaining walls

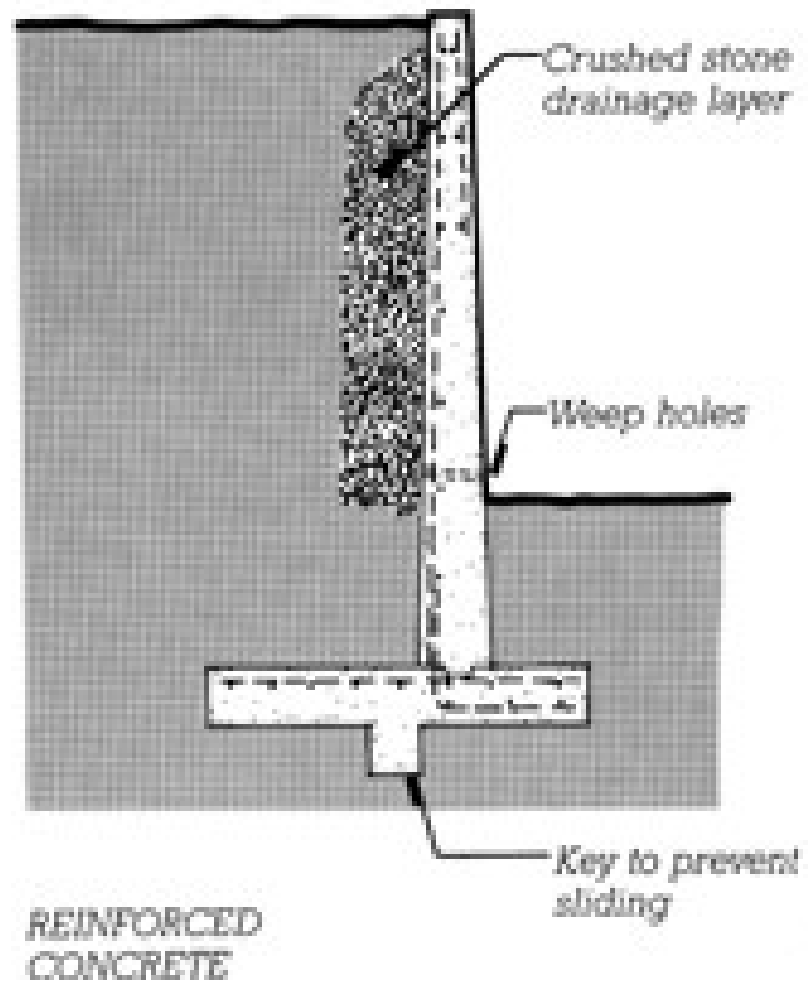
Types of wall failure

- Wall fracture
- Overturning
- Sliding
- Undermining



Retaining walls
Design Elements to Prevent Failure

- Relieve H2O pressure
  - (for all 3 types of failure)
  - – Crushed stone
  - – Weeps
- Overturning
  - – Cantilevered Footing
  - – Reinforcing
- Sliding
  - – Key



Waterproofing

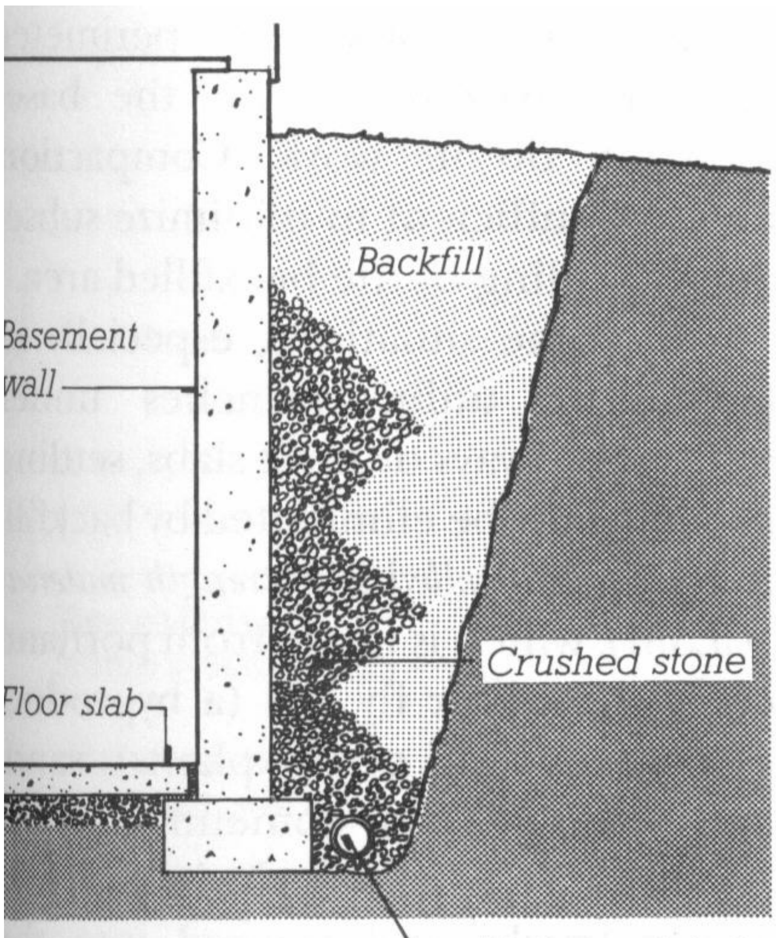
- Structures Below Ground subject to penetration of ground water
- More extreme, if below H_2O table
- Two basic approaches to Waterproofing
  - Waterproof Membranes, or
  - Drainage
  - Generally - both used in tandem

Waterproofing Membranes

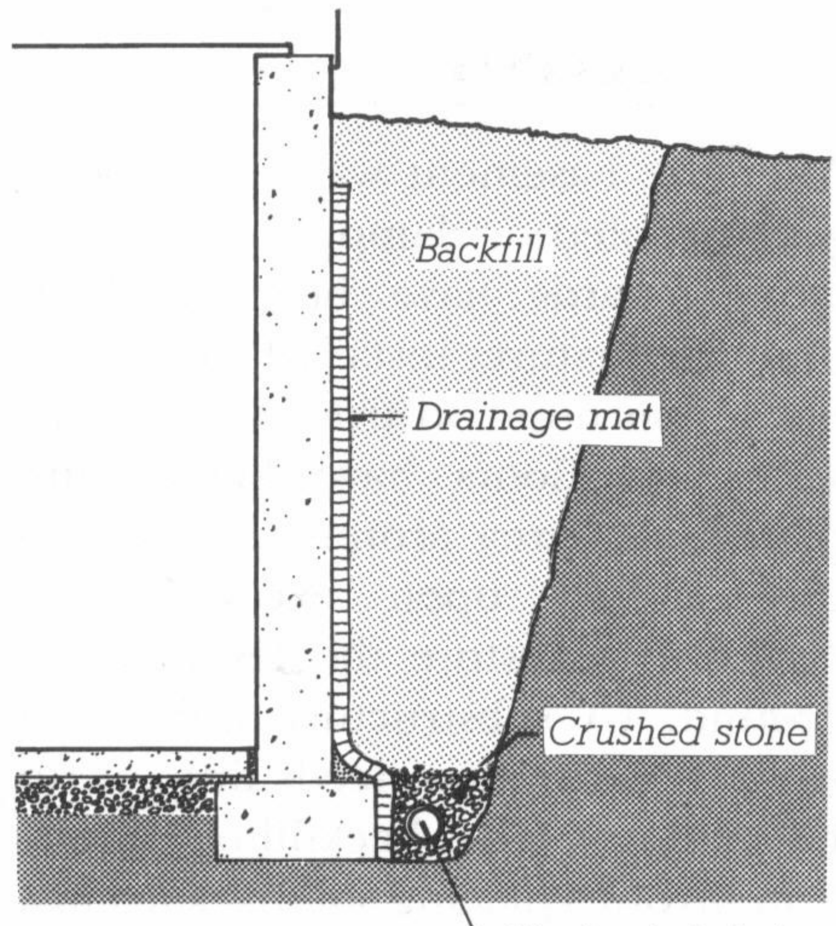
- Materials
  - Liquid or Sheet (Plastic, asphaltic, synthetic rubber)
  - Coatings (asphaltic)
  - Cementitious Plasters & admixtures
  - Bentonite clay
- Accessories
  - Protection Board
  - Waterstop
- Unit of Measure - SF, Mils (thickness)

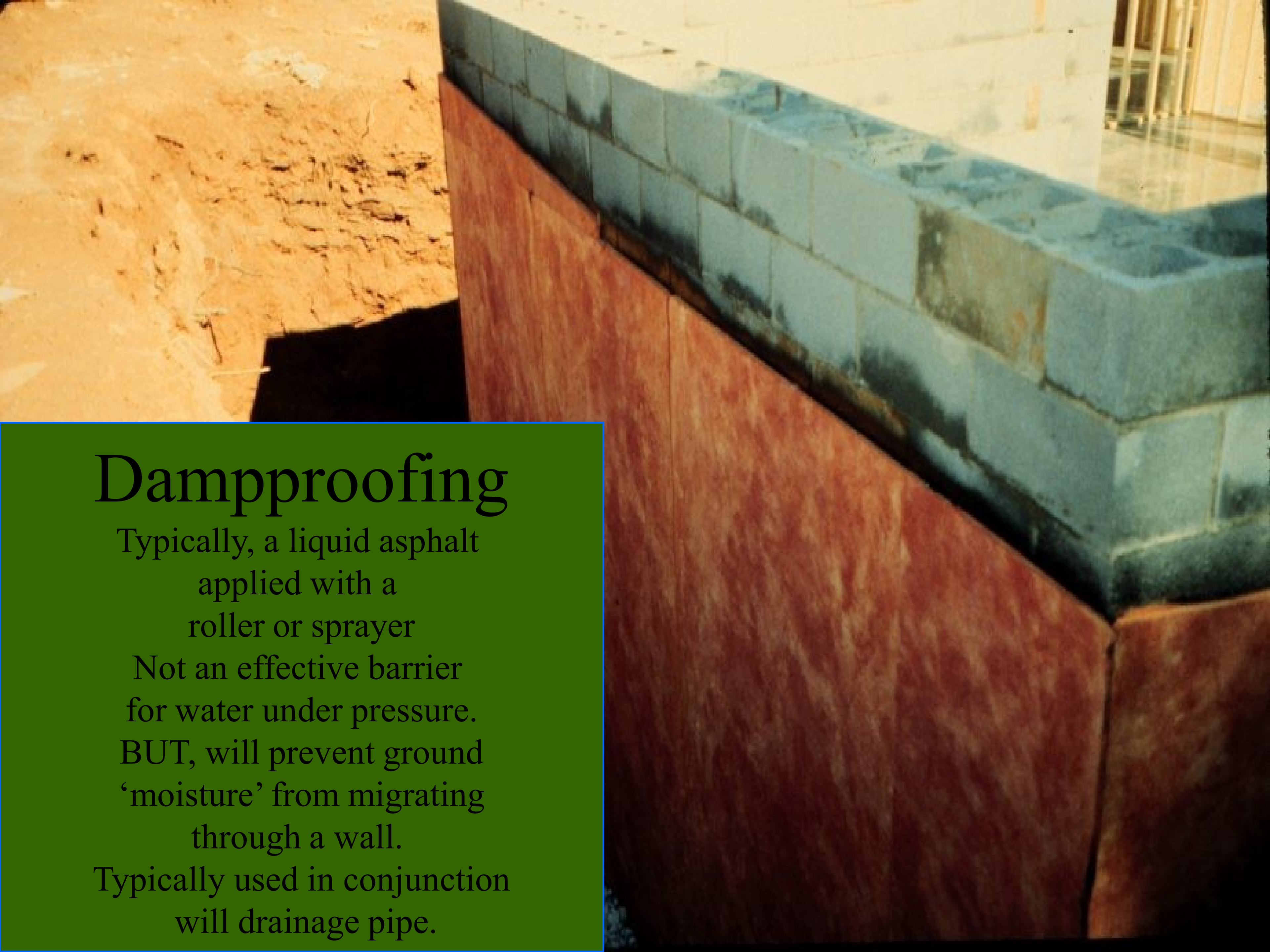
Drainage Methods

<u>Stone & Perforated Pipe</u>



<u>Drainage Mat & Perforated Pipe</u>





Dampproofing

Typically, a liquid asphalt
applied with a
roller or sprayer
Not an effective barrier
for water under pressure.
BUT, will prevent ground
'moisture' from migrating
through a wall.
Typically used in conjunction
will drainage pipe.

2.9 FOUNDATION DESIGN FOR OPTIMAL COST

- **Controlled by many factors:** (i) **Integrated decision-making** and functioning of architects, structural engineers and foundation engineers; (ii) **Building below the water table level** is costly and sometimes damaging to the building; (iii) **Building close to an existing structure to be avoided** (any digging activity on either sites will affect one another and can lead to costly repairs); (iv) **Column or wall load becoming more** than that which can be supported by a shallow foundation (deep foundations are expensive) ; (v) **Uncertainties** can be **avoided by using larger factors of safety** in design of foundations over soils