SOIL & FOUNDATION TYPES:

Subsurface investigations:

- Subsoil conditions are examined using test borings, provided by soil engineer (geotechnical).
- Number of borings and location of borings depends on building type and site conditions.
- Typically for uniform soil conditions borings are spaced 100-150' apart, for more detailed work, where soil footings are closely spaced and soil conditions are not even borings are spaced 50' apart.

  Larger open warehouse type spaces, where fewer columns are present (long span) required less boring samples.
- **Borings must extend to firm Strata** (go through unsuitable foundation soil) and **then extend at least 20 feet more** into bearable soil.
- Location of borings samples are indicated on engineer plan.
- Borings are not taken directly under proposed columns.
- Borings indicate: depth, soil classification (according to the unified soil system), and moisture content and sometimes ground water level is shown as well. (Physical properties: particle size, moisture content, density).
- Soil report recommendation should be based on testing of materials obtained from on site borings and to include:
  1. Bearing capacity of soil.
  2. Foundation design recommendations.
  3. Paving design recommendations.
  4. Compaction of soil.
  5. Lateral strength (active, passive, and coefficient of friction).
  6. Permeability.
  7. Frost depth.

Surface investigations: (Danger Flags)

- High Water Table.
- **Presence of trouble soils: Peat, soft clay, loose silt, or fine water bearing sands.**
- Rock close to the surface (require blasting for excavations).
- Dumps or Fills.
- Evidence of slides or subsidence.

Aboveground indicators of soil conditions:

- Near Buildings – require shoring or earth and existing foundations.
- Rock Outcropping – indicate bedrock, good for bearing and frost resistance, bad for excavations.
- Water (lake) – indicate high water table, some waterproofing of foundations is required.
- Level Terrain – easy site work, fair bearing, but poor drainage.
- Gentle Slopes – easy site work, and excellent drainage.
- Convex Terrain (Ridge) – dry solid place to build.
- Concave Terrain (Valley) – wet soft place to build.
- Steep Terrain – costly excavations, potential erosion, and sliding soils.
- Foliage – some trees indicate moist soil. Large trees indicate solid ground.

Soil Classifications:

- Engineers dealing with soil mechanics devised a simple classification system that will tell the engineer the properties of a given soil.

- The unified soil classification system is based on identifying soils according to their textural and plasticity qualities and on their grouping with respect to behavior.

- Soils are usually found in nature as mixtures with varying proportion of particles of different sizes, each of these components contribute to the soil mixture.

- **Soil is classified on the basis of:**

    1. Percentage of gravel, sand, and fines.
    2. Shape of grain.
    3. **Plasticity and compressibility characteristics**.

- In the unified soil classification system (uscs) the soil is given a descriptive name and a letter symbol indicating its principal characteristics.

- Placement of solid into its respective group is accomplished by visual examination and laboratory tests.

- In the unified soil classification, the terms cobbles, gravel, sand, and fines (silt or clay) are used to designate the size ranges of soil particles.

    Soil particle size ranges from largest to smallest:

    1. Cobbles
    2. Gravel (Coarse + Fine)
    3. Sand (Coarse + Medium + Fine)
    4. Fines consisting of Clay or Silt

- Soil shear strength is made up of cohesion (water content, how sticky it is) and internal friction (based on size of grains). This is determined by triaxial compression testing

Soil Groups:

- Soils are then grouped into three groups consisting of:

  1. Coarse Grained - divided into gravely soils (G) and sands and sandy soils (S)
  2. Fine Grained - divided based on their plasticity properties. (L,H)
  3. Highly Organic - are not subdivided. (Pt)

- Coarse Gained – are soils which composed of gravel and or sands and which contain a wide variety of particles. These are most suitable for foundations when well drained and well confined. They are soils with good bearing value. Particularly the G series (GW, GP, GM, GC).

  Identified on the basis of the percentage amount of gravel and sand.

- Fine Grained – are soils that are Silts and Clays (L,H). Contain **smaller particles of silt and clay.** These are suitable for foundations **but require compactions**. The most suitable of this series (L) is the CL.

  Based on their cohesive properties and permeability.

- Highly Organic – are soils that are usually very compressible and are not suitable for construction. They contain particles of leaves, grass, and branches. Peat, Humus, and swamp soil with highly organic texture are typical of this group (Pt).

  These are identified readily on the basis of color, texture, and odor. Moisture content is also very high in this type of soil.

- Soil names shown on the unified soil classification system are associated with certain grain size and textural properties. This is the case for the coarse grained soils. For silts and clay the names are based on the plasticity basis of the soil.

- Relevant information of samples taken by borings which can aid the geotechnical engineer in determination of foundations includes:

  1. For coarse grain soil – the size of the particles, mineralogical composition, shape of grains, and character of the binder.
  2. For **fine grained soils – strength, moisture, and plasticity.**

- In the preliminary stages, a visual inspection can determine the behavior of the soil when used as component in the construction of a proposed building. Soil can be classified according to the classification categories of the unified soil classification system. (Later on laboratory testing can be performed).

- Strength and consolidation which make up the compaction characteristics of the soil determines its suitability for building foundations.

Soil Problems:

- The problem of uplift pressures in soil can be reduced by having well drained and free draining gravels (GW, GP).
  Uplift pressures can occur in fine grained soils consisting of silts and clays; such soils can cause heaving of foundations and formation of boils.

Due to potential frost action

- Regardless of the frost susceptibility of the various soil groups, two conditions must be present simultaneously before frost action will be a consideration – a source of water during the freezing period and a sufficient period of the freezing temperature to penetrate the ground.

- In general silts and clays (ML, CL, OL) are more susceptible to freezing (as they contain moisture). Well drained granular soils are less susceptible to freezing and creating foundation problems.

Due to drainage Characteristics

- The drainage characteristics of soils are a direct reflection of their permeability. The presence of moisture in base, sub-base and sub-grade materials may cause the development of pore water pressure and loss of strength.

- The gravelly and sandy soils with little or no fines (GW, GP, SW, SP) have excellent drainage characteristics.

- Fine grained soils and highly organic soils have poor drainage characteristics.

Compaction:

- The sheepsfoot and rubber tired rollers are common pieces of equipment used to compact soils. Some advantage is claimed for the sheepsfoot roller in that it leaves a rough surface that affords better bond between layers.

- Granular soils consisting of well graded materials (GW, SW) furnish better compaction results than the poorly graded **soils (GP, SP). Fine grained soils can also be compacted.**

- For most construction projects of any magnitude, it is highly desirable to investigate the compaction characteristics of the soil be means of a field test section.

- Suitability of soils for foundations depends primarily on the strength, cohesion and consolidation characteristic of the soils. The type of structure, load and its use will largely govern the adaptability of a soil as a satisfactory foundation material.

- A soil might be entirely satisfactory for one type of construction but might require special treatment for other building.

- In general, gravel and gravely soils (GW, GP, GM, GC) have good bearing capacity and undergo little consolidation under load.

- Well graded sands (SW) usually also have good bearing capacity.

- Poorly graded sands and silty sands (SP, SM) have variable capacity based on their density.

- Some soils containing silts and clays (ML, CL, OL) are subject to liquefaction and may have poor bearing capacity and large settlements when subject to loads. Of the fine grained soil group CL is probably the better for foundations.

- Organic soils (OL and OH) and highly organic soils (Pt) have poor bearing capacity and usually exhibit large settlement under load.

Foundations:

- For most of the fine grained soils (containing silt and clays) it might be sufficient to use simple spread footings, it is largely depending on the magnitude of the load. The location of the foundations in relation to the soil (need to be aware of foundation walls and hydrostatic pressure as moisture is present in the soil).

- If the soil is poor and structure loads are relatively heavy, then alternate methods are required.

- **Pile foundations might be required in some cases where fine cohesive silt and clay soil is present.** (CH, OH).

- Sometimes it might be desirable and economically feasible to over excavate **remove such soils** that are not of bearing capacity; **can remove compact and fill back or import other engineered soil**.

- The geotechnical engineer based on borings will recommend suitable foundations systems or alternative solutions, also beating capacity, minimum depths, and special design or construction procedures might be established.

- Safe bearing capacity of soil equals to the ultimate bearing capacity divided by a safety factor (usually 2-4). ultimate bearing capacity is defined as the maximum unit pressure a soil can sustain without permitting large amounts of sattelements.

- Bedrock has the highest safe bearing capacity.

- Well graded gravel and sand that are confined and drained have a safe bearing capacity of 3,000 - 12,000 PSF.
- Silts and clays have lower safe bearing capacity of 1,000 – 4,000 PSF.
- Role of Foundations:

1. Transfer the building load to the ground.
2. Anchor building against wind and seismic load.
3. Isolate building from frost heaving.
4. Isolate building from expansive soils.
5. Holds building up from moisture.
6. Provide living spaces (basement, storage).
7. Houses mechanical systems.

- Foundation configurations are: Slab on Grade, Crawl Space, and Basement.

Foundation Types:

Spread Footings:

- Used for most buildings where the loads are light and / or there are strong shallow soils.
- At columns there are single spot square pads where bearing walls have an elongation form. These are almost always reinforced.
- These footing deliver the load directly to the supporting soils.
- Area of spread footing is obtained by dividing the applied force by the soils safe bearing capacity (f=P/A).
- Generally suitable for low rise buildings (1-4 Stories).
- Requires firm soil conditions that are capable of supporting the building on the area of the spread footings.
- When needed footings at columns can be connected together with grade beams to provide more lateral stability in earthquakes.
- These are most widely used because they are most economical.
- Depth of footings should be below the top soil, and frost line, on compacted fill or firm native soil.
- Spread footings should be above the water table.
- Concrete spread footings are at least as thick as the width of the stem.

As the weight of the building increases in relation to the bearing capacity or depth of good bearing soil, the footing needs to expand in size or different systems need to be used.

Drilled Piers or Caissons:

- For expansive soils with low to medium loads, or high loads with rock not too far down, drilled caissons (piers) and grade beams can be used.
- The caissons might be straight or belled out at bottom to spread the load.
- The grade beam is designed to span across the piers and transfer the loads over to a column foundation.
- Caissons deliver the load to soil of stronger capacity which is located not too far down.

Piles:

- for expansive soils or soils that are compressive with heavy loads where deep soils can not take the building load and where soil of better capacity if found deep below.

- There are two types of piles.

    1. Friction piles – used where there is no reasonable bearing stratum and they rely on resistance from skin of pile against the soil.

    2. End bearing – which transfer directly to soil of good bearing capacity.

- The bearing capacity of the piles depends on the structural strength of the pile itself or the strength of the soil, whichever is less.

- Piles can be wood, steel, reinforced concrete, or cast in place concrete piles.

- Cast in place piles are composed of hole drilled in earth and then filled with concrete, it is used for light loads on soft ground and where drilling will not cause collapse. Friction type, obtained from shaft perimeter and surrounding earth.

Mat Foundations:

- Reinforced concrete raft or mats can be used for small light load buildings on very weak or expansive soils such as clays.
- They are often post tensioned concrete.
- They allow the building to float on or in the soil like a raft.
- Can be used for buildings that are 10-20 stories tall where it provides resistance against overturning.
- Can be used where soil requires such a large bearing area and the footing might be spread to the extant that it becomes more economical to pour one large slab (thick), more economical – less forms.
- It is used in lieu of driving piles because can be less expensive and less obtrusive (i.e. less impact on surrounding areas).
- Usually used over expansive clays, silts to let foundation settle without great differences.

General Summery:

- Ranking of Soil for foundations: (from best to unsuitable):

Sand & Gravel	-	Best
Medium & Hard Clays	-	Good
Silts & Soft Clays	-	Poor
Organic Silt and Clays	-	Undesirable
Peat	-	Unsuitable

- The greater the PI – Plasticity Index, Cohesiveness the greater the potential for shrinkage and swelling usually characteristic of clay like soils.

- Non-cohesive are granular soils consisting of gravel and sands.

- Cohesive soils are silts and clays, and also organic.

- Differential settlements in concrete foundations should be limited to ¼ to ½" maximum.

- Generally cost of foundations are 5% of total construction cost.

- Most economical where safe bearing capacity is at least 3000 PSF – Spread Footings.

- Piles are most expensive, 2 or 3 times the price than Spread Footings.