Residential Foundation

- **Recognizing Shifts in the Home Foundation**
  Recognizing Shifts in the Home Foundation Subtle Clues That Indicate Structural Changes Early Indicators of Potential Foundation Damage Observing Signs of Settlement in Floors Identifying Hairline Cracks and Surface Gaps Evaluating Tilted Door Frames and Window Alignment Understanding Bowed Wall Patterns in Basements Detecting Weak Spots Beneath Interior Flooring Uncovering Gradual Shifts in Support Beams Pinpointing Areas Prone to Moisture Intrusion Checking for Stair-Step Cracks Along Walls Preventing Growth of Small Foundation Cracks
- **Exploring Slab on Grade Construction Details**
  Exploring Slab on Grade Construction Details Comparing Pier and Beam Home Foundations Recognizing Basement Foundations in Older Houses Understanding the Basics of Piering Strategies Exploring Techniques for Slab Jacking Projects Grasping the Scope of Epoxy Injection Repairs Assessing Helical Piers for Added Support Considering Carbon Fiber Solutions for Wall Reinforcement Discovering Polyurethane Foam Applications Investigating Steel Piers in Home Restoration Reviewing Concrete Piers for Structural Stability Selecting Appropriate Methods for Specific Soil Types
- **About Us**

roadblock. Among the options, pier and beam foundations stand out as a popular choice, especially in certain regions and for specific types of homes. Understanding the nuances of pier and beam foundations, and comparing them with other types, can help in making an informed decision that suits both the structure of the home and the local environmental conditions.

Pier and beam foundations, also known as post and beam or crawl space foundations, consist of a series of piers, typically made of concrete, that are embedded into the ground. These piers support a series of beams, which in turn hold up the floor joists and the rest of the home. This type of foundation creates a raised structure, often with a crawl space between the ground and the bottom of the house. This space can be used for storage, plumbing, and electrical systems, and it also allows for easier access for maintenance and repairs.

One of the primary advantages of pier and beam foundations is their adaptability to different soil types and conditions. In areas prone to expansive soils, which swell and shrink with moisture changes, pier and beam foundations can be more forgiving than slab foundations. The raised structure allows the home to shift slightly without causing significant damage, whereas a slab might crack under similar conditions. This flexibility makes pier and beam foundations particularly popular in regions like Texas, where the soil can be quite challenging.

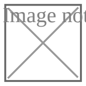
Another benefit of pier and beam foundations is their potential for better insulation and ventilation. The crawl space can be insulated, which can contribute to a more energy-efficient home. Additionally, the space allows for better air circulation, which can help in reducing moisture-related issues like mold and mildew. This is a significant advantage over slab foundations, which can sometimes lead to moisture problems if not properly sealed and insulated.

However, pier and beam foundations do come with their own set of challenges. The crawl space can be a haven for pests if not properly sealed and maintained. It also requires more maintenance than a slab foundation, as the piers and beams need to be inspected regularly for signs of settling, shifting, or damage. Additionally, the initial cost of constructing a pier and beam foundation can be higher than that of a slab foundation, although the long-term benefits might outweigh these costs in certain situations.

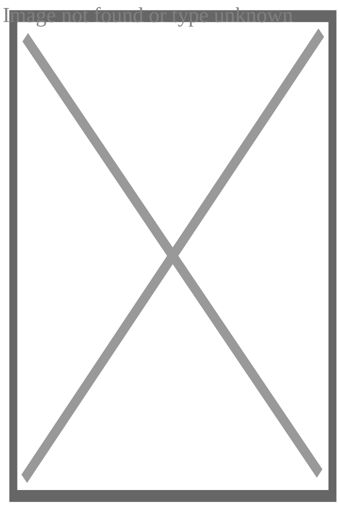
When comparing pier and beam foundations to other types, such as slab or basement foundations, it's essential to consider the specific needs of the home and the local environment. For instance, in areas prone to flooding, a pier and beam foundation might be preferable, as it allows the home to be elevated above potential flood levels. On the other hand, in colder climates, a basement foundation might be more suitable, as it can provide additional living space and better insulation.

In conclusion, pier and beam foundations offer a versatile and adaptable option for home construction, particularly in regions with challenging soil conditions. While they may require more maintenance and have a higher initial cost, the benefits of flexibility, potential energy efficiency, and better ventilation can make them a worthwhile choice for many homeowners. As with any significant decision in home building, it's crucial to weigh the pros and cons of pier and beam foundations against other options and consider the specific needs of the home and the local environment before making a final decision.

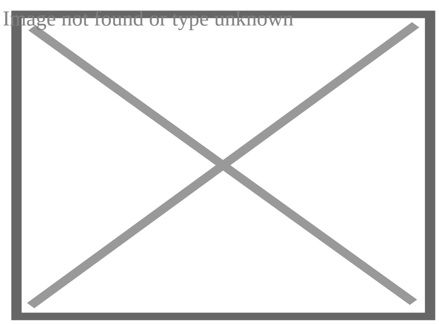
About soil mechanics



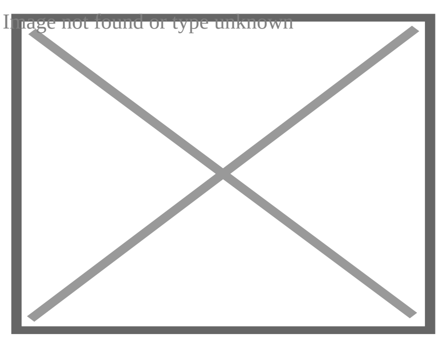
This article **may be too long to read and navigate comfortably**. Consider splitting content into sub-articles, condensing it, or adding subheadings. Please discuss this issue on the article's talk page. *(February 2025)*



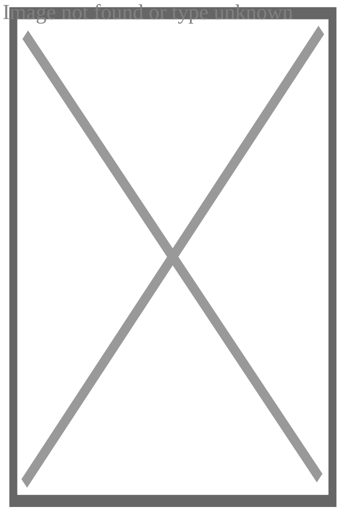
The Leaning Tower of Pisa – an example of a problem due to deformation of soil



Slope instability issues for a temporary flood control levee in North Dakota, 2009



Earthwork in Germany



Fox Glacier, New Zealand: Soil produced and transported by intense weathering and erosion

Soil mechanics is a branch of soil physics and applied mechanics that describes the behavior of soils. It differs from fluid mechanics and solid mechanics in the sense that soils consist of a heterogeneous mixture of fluids (usually air and water) and particles (usually clay, silt, sand, and gravel) but soil may also contain organic solids and other matter.[1][2][3][4] Along with rock mechanics, soil mechanics provides the theoretical basis for analysis in geotechnical engineering,[5] a subdiscipline of civil engineering, and engineering geology, a subdiscipline of geology. Soil mechanics is used to analyze the deformations of and flow of fluids within natural and man-made structures that are supported on or made of soil, or structures that are buried in soils.[6] Example applications are building and bridge foundations, retaining walls, dams, and buried pipeline systems. Principles of soil mechanics are also used in related disciplines such as geophysical engineering, coastal engineering, agricultural engineering, and hydrology.

This article describes the genesis and composition of soil, the distinction between *pore water pressure* and inter-granular *effective stress*, capillary action of fluids in the soil pore spaces, *soil classification*, *seepage* and *permeability*, time dependent change of volume due to squeezing water out of tiny pore spaces, also known as *consolidation*, *shear strength* and stiffness of soils. The shear strength of soils is primarily derived from friction between the particles and interlocking, which are very sensitive to the effective stress.[7][6] The article concludes with some examples of applications of the principles of soil mechanics such as slope stability, lateral earth pressure on retaining walls, and bearing capacity of foundations.

Genesis and composition of soils

[edit]

Genesis

[edit]

The primary mechanism of soil creation is the weathering of rock. All rock types (igneous rock, metamorphic rock and sedimentary rock) may be broken down into small particles to create soil. Weathering mechanisms are physical weathering, chemical weathering, and biological weathering [1][2][3] Human activities such as excavation, blasting, and waste disposal, may also create soil. Over geologic time, deeply buried soils may be altered by pressure and temperature to become metamorphic or sedimentary rock, and if melted and solidified again, they would complete the geologic cycle by becoming igneous rock.[3]

Physical weathering includes temperature effects, freeze and thaw of water in cracks, rain, wind, impact and other mechanisms. Chemical weathering includes dissolution of matter composing a rock and precipitation in the form of another mineral. Clay minerals, for example can be formed by weathering of feldspar, which is the most common mineral present in igneous rock.

The most common mineral constituent of silt and sand is quartz, also called silica, which has the chemical name silicon dioxide. The reason that feldspar is most common in rocks but silica is more prevalent in soils is that feldspar is much more soluble than silica.

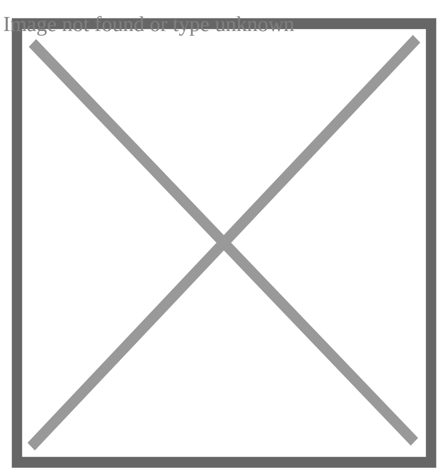
Silt, Sand, and Gravel are basically little pieces of broken rocks.

According to the Unified Soil Classification System, silt particle sizes are in the range of 0.002 mm to 0.075 mm and sand particles have sizes in the range of 0.075 mm to 4.75 mm.

Gravel particles are broken pieces of rock in the size range 4.75 mm to 100 mm. Particles larger than gravel are called cobbles and boulders.[1][2]

Transport

[edit]



Example soil horizons. a) top soil and colluvium b) mature residual soil c) young residual soil d) weathered rock

Soil deposits are affected by the mechanism of transport and deposition to their location. Soils that are not transported are called residual soils—they exist at the same location as the rock from which they were generated. Decomposed granite is a common example of a residual soil. The common mechanisms of transport are the actions of gravity, ice, water, and wind. Wind blown soils include dune sands and loess. Water carries particles of different size depending on the speed of the water, thus soils transported by water are graded according to their size. Silt and clay may settle out in a lake, and gravel and sand collect at the bottom of a river bed. Wind blown soil deposits (aeolian soils) also tend to be sorted according to their grain size. Erosion at the base of glaciers is powerful enough to pick up large rocks and boulders as well as soil; soils dropped by melting ice can be a well graded mixture of widely varying particle sizes. Gravity on its own may also carry particles down from the top of a mountain to make a pile of soil and boulders at the base; soil deposits transported by gravity are called colluvium.[1][2]

The mechanism of transport also has a major effect on the particle shape. For example, low velocity grinding in a river bed will produce rounded particles. Freshly fractured colluvium particles often have a very angular shape.

Soil composition

[edit]

Soil mineralogy

[edit]

Silts, sands and gravels are classified by their size, and hence they may consist of a variety of minerals. Owing to the stability of quartz compared to other rock minerals, quartz is the most common constituent of sand and silt. Mica, and feldspar are other common minerals present in sands and silts.[1] The mineral constituents of gravel may be more similar to that of the parent rock.

The common clay minerals are montmorillonite or smectite, illite, and kaolinite or kaolin. These minerals tend to form in sheet or plate like structures, with length typically ranging between $10^{?7}$ m and $4x10^{?6}$ m and thickness typically ranging between $10^{?9}$ m and $2x10^{?6}$ m, and they have a relatively large specific surface area. The specific surface area (SSA) is defined as the ratio of the surface area of particles to the mass of the particles. Clay minerals typically have specific surface areas in the range of 10 to 1,000 square meters per gram of solid.[3] Due to the large surface area available for chemical, electrostatic, and van der Waals interaction, the mechanical behavior of clay minerals is very sensitive to the amount of pore fluid available and the type and amount of dissolved ions in the pore fluid.[1]

The minerals of soils are predominantly formed by atoms of oxygen, silicon, hydrogen, and aluminum, organized in various crystalline forms. These elements along with calcium, sodium, potassium, magnesium, and carbon constitute over 99 per cent of the solid mass of soils.[1]

Grain size distribution

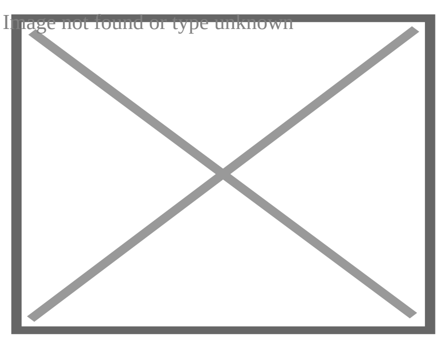
[edit]
Main article: Soil gradation

Soils consist of a mixture of particles of different size, shape and mineralogy. Because the size of the particles obviously has a significant effect on the soil behavior, the grain size and grain size distribution are used to classify soils. The grain size distribution describes the relative proportions of particles of various sizes. The grain size is often visualized in a cumulative distribution graph which, for example, plots the percentage of particles finer than a given size as a function of size. The median grain size, $\displaystyle D_{50}$ Image not found or type unknown, is the size for which 50% of the particle mass consists of finer particles. Soil behavior, especially the hydraulic conductivity, tends to be dominated by the smaller particles, hence, the term "effective size", denoted by $\displaystyle D_{10}$ Image not found or type unknown, is defined as the size for which 10% of the particle mass consists of finer particles.

Sands and gravels that possess a wide range of particle sizes with a smooth distribution of particle sizes are called *well graded* soils. If the soil particles in a sample are predominantly in a relatively narrow range of sizes, the sample is *uniformly graded*. If a soil sample has distinct gaps in the gradation curve, e.g., a mixture of gravel and fine sand, with no coarse sand, the sample may be *gap graded*. *Uniformly graded* and *gap graded* soils are both considered to be *poorly graded*. There are many methods for measuring particle-size distribution. The two traditional methods are sieve analysis and hydrometer analysis.

Sieve analysis

[edit]



Sieve

The size distribution of gravel and sand particles are typically measured using sieve analysis. The formal procedure is described in ASTM D6913-04(2009).[8] A stack of sieves with accurately dimensioned holes between a mesh of wires is used to separate the particles into size bins. A known volume of dried soil, with clods broken down to individual particles, is put into the top of a stack of sieves arranged from coarse to fine. The stack of sieves is shaken for a standard period of time so that the particles are sorted into size bins. This method works reasonably well for particles in the sand and gravel size range. Fine particles tend to stick to each other, and hence the sieving process is not an effective method. If there are a lot of fines (silt and clay) present in the soil it may be necessary to run water through the sieves to wash the coarse particles and clods through.

A variety of sieve sizes are available. The boundary between sand and silt is arbitrary. According to the Unified Soil Classification System, a #4 sieve (4 openings per inch) having 4.75 mm opening size separates sand from gravel and a #200 sieve with an 0.075 mm opening separates sand from silt and clay. According to the British standard, 0.063 mm is the boundary between sand and silt, and 2 mm is the boundary between sand and gravel.[3]

Hydrometer analysis

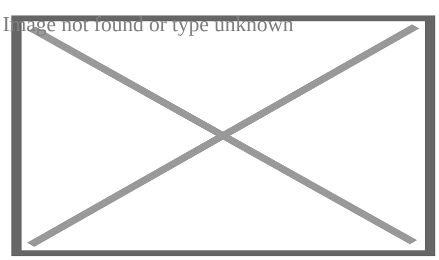
[edit]

The classification of fine-grained soils, i.e., soils that are finer than sand, is determined primarily by their Atterberg limits, not by their grain size. If it is important to determine the grain size distribution of fine-grained soils, the hydrometer test may be performed. In the hydrometer tests, the soil particles are mixed with water and shaken to produce a dilute suspension in a glass cylinder, and then the cylinder is left to sit. A hydrometer is used to measure the density of the suspension as a function of time. Clay particles may take several hours to settle past the depth of measurement of the hydrometer. Sand particles may take less than a second. Stokes' law provides the theoretical basis to calculate the relationship between sedimentation velocity and particle size. ASTM provides the detailed procedures for performing the Hydrometer test.

Clay particles can be sufficiently small that they never settle because they are kept in suspension by Brownian motion, in which case they may be classified as colloids.

Mass-volume relations

[edit]



A phase diagram of soil indicating the masses and volumes of air, solid, water, and voids

There are a variety of parameters used to describe the relative proportions of air, water and solid in a soil. This section defines these parameters and some of their interrelationships.[2][6] The basic notation is as follows:

- V_a, V_w, and V_s represent the volumes of air, water and solids in a soil mixture;
- W_a, W_w, and W_s represent the weights of air, water and solids in a soil mixture;
- M_a, M_w, and M_s represent the masses of air, water and solids in a soil mixture;
- ρ_a, ρ_w, and ρ_s represent the densities of the constituents (air, water and solids) in a soil mixture;

Note that the weights, W, can be obtained by multiplying the mass, M, by the acceleration due to gravity, g; e.g., $W_s=M_sg$

Specific Gravity is the ratio of the density of one material compared to the density of pure water ($\rho_w=1g/cm^3$).

Specific gravity of solids, $G_s=\frac{\rho_s}{\rho_w}$

Note that specific weight, conventionally denoted by the symbol γ may be obtained by multiplying the density (ρ) of a material by the acceleration due to gravity, g.

Density, *bulk density*, or *wet density*, ρ, are different names for the density of the mixture, i.e., the total mass of air, water, solids divided by the total volume of air water and solids (the mass of air is assumed to be zero for practical purposes):

$$\rho=\frac{M_s+M_w}{V_s+V_w+V_a}=\frac{M_t}{V_t}$$

Dry density, ρ_d, is the mass of solids divided by the total volume of air water and solids:

$$\rho_d=\frac{M_s}{V_s+V_w+V_a}=\frac{M_s}{V_t}$$

Buoyant density, ρ', defined as the density of the mixture minus the density of water is useful if the soil is submerged under water:

$$\rho'=\rho\ -\rho_w$$

where ρ_w is the density of water

Water content, w is the ratio of mass of water to mass of solid. It is easily measured by weighing a sample of the soil, drying it out in an oven and re-weighing. Standard procedures are described by ASTM.

$$w=\frac{M_w}{M_s}=\frac{W_w}{W_s}$$

Image not found or type unknown

Void ratio, e, is the ratio of the volume of voids to the volume of solids:

$$e=\frac{V_v}{V_s}=\frac{V_v}{V_t-V_v}=\frac{n}{1-n}$$

Image not found or type unknown

Porosity, n, is the ratio of volume of voids to the total volume, and is related to the void ratio:

$$n=\frac{V_v}{V_t}=\frac{V_v}{V_s+V_v}=\frac{e}{1+e}$$

Image not found or type unknown

Degree of saturation, S, is the ratio of the volume of water to the volume of voids:

$$S=\frac{V_w}{V_v}$$

Image not found or type unknown

From the above definitions, some useful relationships can be derived by use of basic algebra.

$$\rho =\frac{(G_s+Se)\rho _w}{1+e}$$

Image not found or type unknown

$$\rho =\frac{(1+w)G_s\rho _w}{1+e}$$

Image not found or type unknown

$$w=\frac{Se}{G_s}$$

Image not found or type unknown

Soil classification

[edit]

Geotechnical engineers classify the soil particle types by performing tests on disturbed (dried, passed through sieves, and remolded) samples of the soil. This provides information about the characteristics of the soil grains themselves. Classification of the types of grains present in a soil does not[*clarification needed*] account for important effects of the *structure* or *fabric* of the soil, terms that describe compactness of the particles and patterns in the arrangement of particles in a load carrying framework as well as the pore size and pore fluid distributions. Engineering geologists also classify soils based on their genesis and depositional history.

Classification of soil grains

[edit]

In the US and other countries, the Unified Soil Classification System (USCS) is often used for soil classification. Other classification systems include the British Standard BS 5930 and the AASHTO soil classification system.[3]

Classification of sands and gravels

[edit]

In the USCS, gravels (given the symbol *G*) and sands (given the symbol *S*) are classified according to their grain size distribution. For the USCS, gravels may be given the classification symbol *GW* (well-graded gravel), *GP* (poorly graded gravel), *GM* (gravel with a large amount of silt), or *GC* (gravel with a large amount of clay). Likewise sands may be classified as being *SW*, *SP*, *SM* or *SC*. Sands and gravels with a small but non-negligible amount of fines (5–12%) may be given a dual classification such as *SW-SC*.

Atterberg limits

[edit]

Clays and Silts, often called 'fine-grained soils', are classified according to their Atterberg limits; the most commonly used Atterberg limits are the *liquid limit* (denoted by *LL* or \displaystyle w_l Image not found of type Unknown), *plastic limit* (denoted by *PL* or \displaystyle w_p Image not found of type Unknown), and *shrinkage limit* (denoted by *SL*).

The liquid limit is the water content at which the soil behavior transitions from a plastic solid to a liquid. The plastic limit is the water content at which the soil behavior transitions from that of a plastic solid to a brittle solid. The Shrinkage Limit corresponds to a water content below which the soil will not shrink as it dries. The consistency of fine grained soil varies in proportional to the water content in a soil.

As the transitions from one state to another are gradual, the tests have adopted arbitrary definitions to determine the boundaries of the states. The liquid limit is determined by measuring the water content for which a groove closes after 25 blows in a standard test.[9] [*clarification needed*] Alternatively, a fall cone test apparatus may be used to measure the liquid limit. The undrained shear strength of remolded soil at the liquid limit is approximately 2 kPa.[4][10] The plastic limit is the water content below which it is not possible to roll by hand the soil into 3 mm diameter cylinders. The soil cracks or breaks up as it is rolled down to this diameter. Remolded soil at the plastic limit is quite stiff, having an undrained shear strength of the order of about 200 kPa.[4][10]

The *plasticity index* of a particular soil specimen is defined as the difference between the liquid limit and the plastic limit of the specimen; it is an indicator of how much water the soil particles in the specimen can absorb, and correlates with many engineering properties like permeability, compressibility, shear strength and others. Generally, the clay having high plasticity have lower permeability and also they are also difficult to be compacted.

Classification of silts and clays

[edit]

According to the Unified Soil Classification System (USCS), silts and clays are classified by plotting the values of their plasticity index and liquid limit on a plasticity chart. The A-Line on the chart separates clays (given the USCS symbol *C*) from silts (given the symbol *M*). LL=50% separates high plasticity soils (given the modifier symbol *H*) from low plasticity soils (given the modifier symbol *L*). A soil that plots above the A-line and has LL>50% would, for example, be classified as *CH*. Other possible classifications of silts and clays are *ML*, *CL* and *MH*. If the Atterberg limits plot in the"hatched" region on the graph near the origin, the soils are given the dual classification 'CL-ML'.

Indices related to soil strength

[edit]

Liquidity index

[edit]

The effects of the water content on the strength of saturated remolded soils can be quantified by the use of the *liquidity index*, *LI*:

$$\displaystyle LI=\frac{w-PL}{LL-PL}$$

Image not found or type unknown

When the LI is 1, remolded soil is at the liquid limit and it has an undrained shear strength of about 2 kPa. When the soil is at the plastic limit, the LI is 0 and the undrained shear strength is about 200 kPa.[4][11]

Relative density

[edit]

The density of sands (cohesionless soils) is often characterized by the relative density, D_r

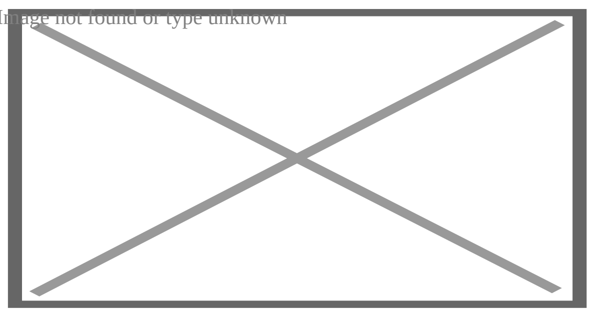
$$D_r=\frac{e_{max}-e}{e_{max}-e_{min}}100\%$$

where: e_{max} is the "maximum void ratio" corresponding to a very loose state, e_{min} is the "minimum void ratio" corresponding to a very dense state and e is the *in situ* void ratio. Methods used to calculate relative density are defined in ASTM D4254-00(2006).[12]

Thus if $D_r=100\%$ the sand or gravel is very dense, and if $D_r=0\%$ the soil is extremely loose and unstable.

Seepage: steady state flow of water

[edit]
This section is an excerpt from Seepage.[edit]



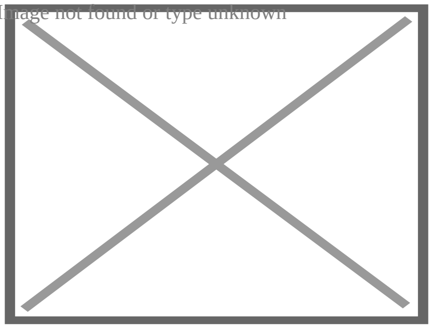
A cross section showing the water table varying with surface topography as well as a perched water table

In soil mechanics, seepage is the movement of water through soil. If fluid pressures in a soil deposit are uniformly increasing with depth according to $u=\gamma_w z_w$ where z_w is the depth below the water table, then hydrostatic conditions will prevail and the fluids will *not* be flowing through the soil. However, if the water table is sloping or there is a perched water table as indicated in the accompanying sketch, then seepage will occur. For steady state seepage, the seepage velocities are not varying with time. If the water tables are changing levels with time, or if the soil is in the process of consolidation, then steady state conditions do not apply.

Effective stress and capillarity: hydrostatic conditions

[edit]

Image not found or type unknown



Spheres immersed in water, reducing effective stress

Main article: Effective stress

To understand the mechanics of soils it is necessary to understand how normal stresses and shear stresses are shared by the different phases. Neither gas nor liquid provide significant resistance to shear stress. The shear resistance of soil is provided by friction and interlocking of the particles. The friction depends on the intergranular contact stresses between solid particles. The normal stresses, on the other hand, are shared by the fluid and the particles.[7] Although the pore air is relatively compressible, and hence takes little normal stress in most geotechnical problems, liquid water is relatively incompressible and if the voids are saturated with water, the pore water must be squeezed out in order to pack the particles closer together.

The principle of effective stress, introduced by Karl Terzaghi, states that the effective stress *?′* (i.e., the average intergranular stress between solid particles) may be calculated by a simple subtraction of the pore pressure from the total stress:

$$\displaystyle \sigma '=\sigma -u\,$$ [7]

Image not found or type unknown

where *?* is the total stress and *u* is the pore pressure. It is not practical to measure *?′* directly, so in practice the vertical effective stress is calculated from the pore pressure and vertical total stress. The distinction between the terms pressure and stress is also important. By definition, pressure at a point is equal in all directions but stresses at a point can be different in different directions. In soil mechanics, compressive stresses and pressures are considered to be positive and tensile stresses are considered to be negative, which is different from the solid mechanics sign convention for stress.

Total stress

[edit]

For level ground conditions, the total vertical stress at a point, $\displaystyle \sigma _v$ Image not found or type unknown on average, is the weight of everything above that point per unit area. The vertical stress beneath a uniform surface layer with density $\displaystyle \rho$ Image not found or type unknown and thickness $\displaystyle H$ Image not found or type unknown is, for example:

$$\sigma_v=\rho gH=\gamma H$$

where g is the acceleration due to gravity, and γ is the unit weight of the overlying layer. If there are multiple layers of soil or water above the point of interest, the vertical stress may be calculated by summing the product of the unit weight and thickness of all of the overlying layers. Total stress increases with increasing depth in proportion to the density of the overlying soil.

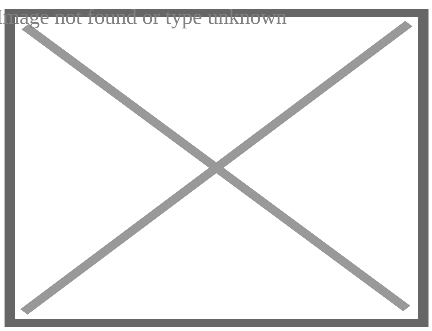
It is not possible to calculate the horizontal total stress in this way. Lateral earth pressures are addressed elsewhere.

Pore water pressure

[edit]
Main article: Pore water pressure

Hydrostatic conditions

[edit]



Water is drawn into a small tube by surface tension. Water pressure, u, is negative above and positive below the free water surface.

If the soil pores are filled with water that is not flowing but is static, the pore water pressures will be hydrostatic. The water table is located at the depth where the water pressure is equal to the atmospheric pressure. For hydrostatic conditions, the water pressure increases linearly with depth below the water table:

$$u=\rho_w g z_w$$

where ρ_w is the density of water, and z_w is the depth below the water table.

Capillary action

[edit]

Due to surface tension, water will rise up in a small capillary tube above a free surface of water. Likewise, water will rise up above the water table into the small pore spaces around the soil particles. In fact the soil may be completely saturated for some distance above the water table. Above the height of capillary saturation, the soil may be wet but the water content will decrease with elevation. If the water in the capillary zone is not moving, the water pressure obeys the equation of hydrostatic equilibrium, $u=\rho_{w}gz_{w}$, but note that z_{w} is negative above the water table. Hence, hydrostatic water pressures are negative above the water table. The thickness of the zone of capillary saturation depends on the pore size, but typically, the heights vary between a centimeter or so for coarse sand to tens of meters for a silt or clay.[3] In fact the pore space of soil is a uniform fractal e.g. a set of uniformly distributed D-dimensional fractals of average linear size L. For the clay soil it has been found that L=0.15 mm and D=2.7.[13]

The surface tension of water explains why the water does not drain out of a wet sand castle or a moist ball of clay. Negative water pressures make the water stick to the particles and pull the particles to each other, friction at the particle contacts make a sand castle stable. But as soon as a wet sand castle is submerged below a free water surface, the negative pressures are lost and the castle collapses. Considering the effective stress equation, $\sigma '=\sigma -u$, if the water pressure is negative, the effective stress may be positive, even on a free surface (a surface where the total normal stress is zero). The negative pore pressure pulls the particles together and causes compressive particle to particle contact forces. Negative pore pressures in clayey soil can be much more powerful than those in sand. Negative pore pressures explain why clay soils shrink when they dry and swell as they are wetted. The swelling and shrinkage can cause major distress, especially to light structures and roads.[14]

Later sections of this article address the pore water pressures for seepage and consolidation problems.

Water at particle contacts

- Image not found or type unknown

  Water at particle contacts
- Intergranular contact force due to surface tension

  Image not found or type unknown

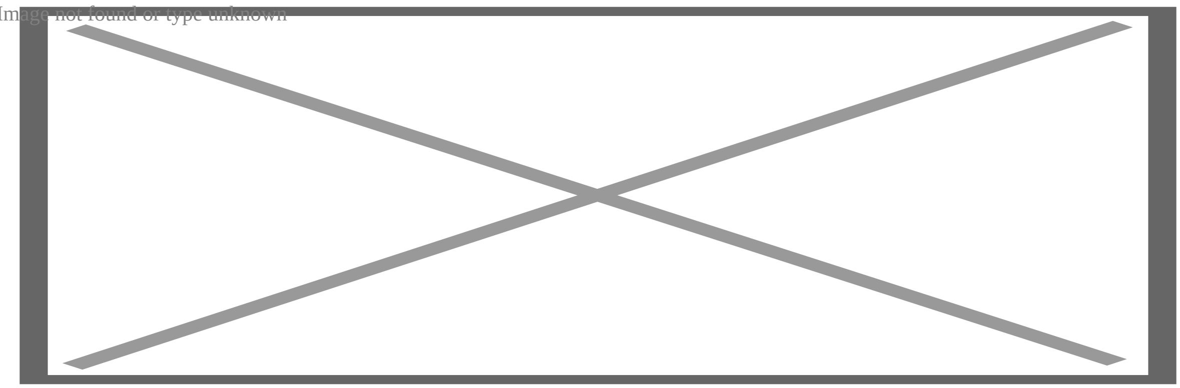
  Intergranular contact force due to surface tension

Shrinkage caused by drying

- Image not found or type unknown
  Shrinkage caused by drying

Consolidation: transient flow of water

[edit]
Main article: Consolidation (soil)

Image not found or type unknown


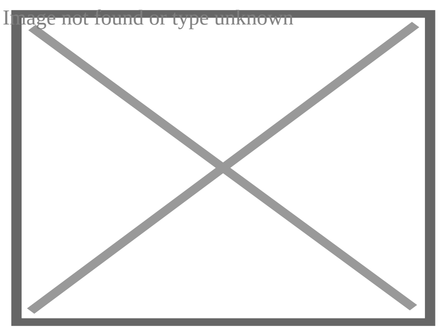
Consolidation analogy. The piston is supported by water underneath and a spring. When a load is applied to the piston, water pressure increases to support the load. As the water slowly leaks through the small hole, the load is transferred from the water pressure to the spring force.

Consolidation is a process by which soils decrease in volume. It occurs when stress is applied to a soil that causes the soil particles to pack together more tightly, therefore reducing volume. When this occurs in a soil that is saturated with water, water will be squeezed out of the soil. The time required to squeeze the water out of a thick deposit of clayey soil layer might be years. For a layer of sand, the water may be squeezed out in a matter of seconds. A building foundation or construction of a new embankment will cause the soil below to consolidate and this will cause settlement which in turn may cause distress to the building or embankment. Karl Terzaghi developed the theory of one-dimensional consolidation which enables prediction of the amount of settlement and the time required for the settlement to occur.[15] Afterwards, Maurice Biot fully developed the three-dimensional soil consolidation theory, extending the one-dimensional model previously developed by Terzaghi to more general hypotheses and introducing the set of basic equations of Poroelasticity.[7] Soils are tested with an oedometer test to determine their compression index and coefficient of consolidation.

When stress is removed from a consolidated soil, the soil will rebound, drawing water back into the pores and regaining some of the volume it had lost in the consolidation process. If the stress is reapplied, the soil will re-consolidate again along a recompression curve, defined by the recompression index. Soil that has been consolidated to a large pressure and has been subsequently unloaded is considered to be *overconsolidated*. The maximum past vertical effective stress is termed the *preconsolidation stress*. A soil which is currently experiencing the maximum past vertical effective stress is said to be *normally consolidated*. The *overconsolidation ratio*, (OCR) is the ratio of the maximum past vertical effective stress to the current vertical effective stress. The OCR is significant for two reasons: firstly, because the compressibility of normally consolidated soil is significantly larger than that for overconsolidated soil, and secondly, the shear behavior and dilatancy of clayey soil are related to the OCR through critical state soil mechanics; highly overconsolidated clayey soils are dilatant, while normally consolidated soils tend to be contractive.[2][3][4]

Shear behavior: stiffness and strength

[edit]
Main article: shear strength (soil)



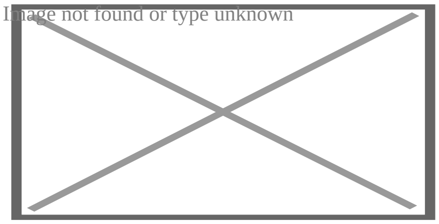
Typical stress strain curve for a drained dilatant soil

The shear strength and stiffness of soil determines whether or not soil will be stable or how much it will deform. Knowledge of the strength is necessary to determine if a slope will be stable, if a building or bridge might settle too far into the ground, and the limiting pressures on a retaining wall. It is important to distinguish between failure of a soil element and the failure of a geotechnical structure (e.g., a building foundation, slope or retaining wall); some soil elements may reach their peak strength prior to failure of the structure. Different criteria can be used to define the "shear strength" and the "yield point" for a soil element from a stress–strain curve. One may define the peak shear strength as the peak of a stress–strain curve, or the shear strength at critical state as the value after large strains when the shear resistance levels off. If the stress–strain curve does not stabilize before the end of shear strength test, the "strength" is sometimes considered to be the shear resistance at 15–20% strain.[14] The shear strength of soil depends on many factors including the effective stress and the void ratio.

The shear stiffness is important, for example, for evaluation of the magnitude of deformations of foundations and slopes prior to failure and because it is related to the shear wave velocity. The slope of the initial, nearly linear, portion of a plot of shear stress as a function of shear strain is called the shear modulus

Friction, interlocking and dilation

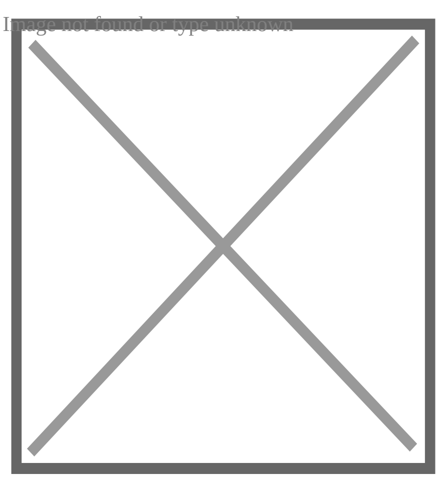
[edit]



Angle of repose

Soil is an assemblage of particles that have little to no cementation while rock (such as sandstone) may consist of an assembly of particles that are strongly cemented together by chemical bonds. The shear strength of soil is primarily due to interparticle friction and therefore, the shear resistance on a plane is approximately proportional to the effective normal stress on that plane.[3] The angle of internal friction is thus closely related to the maximum stable slope angle, often called the angle of repose.

But in addition to friction, soil derives significant shear resistance from interlocking of grains. If the grains are densely packed, the grains tend to spread apart from each other as they are subject to shear strain. The expansion of the particle matrix due to shearing was called dilatancy by Osborne Reynolds.[11] If one considers the energy required to shear an assembly of particles there is energy input by the shear force, T, moving a distance, x and there is also energy input by the normal force, N, as the sample expands a distance, y.[11] Due to the extra energy required for the particles to dilate against the confining pressures, dilatant soils have a greater peak strength than contractive soils. Furthermore, as dilative soil grains dilate, they become looser (their void ratio increases), and their rate of dilation decreases until they reach a critical void ratio. Contractive soils become denser as they shear, and their rate of contraction decreases until they reach a critical void ratio.



A critical state line separates the dilatant and contractive states for soil.

The tendency for a soil to dilate or contract depends primarily on the confining pressure and the void ratio of the soil. The rate of dilation is high if the confining pressure is small and the void ratio is small. The rate of contraction is high if the confining pressure is large and the void ratio is large. As a first approximation, the regions of contraction and dilation are separated by the critical state line.

Failure criteria

[edit]

After a soil reaches the critical state, it is no longer contracting or dilating and the shear stress on the failure plane τ_{crit} is determined by the effective normal stress on the failure plane σ_n' and critical state friction angle ϕ_{crit}'

$$\tau_{crit}=\sigma_n'\tan \phi_{crit}'$$

The peak strength of the soil may be greater, however, due to the interlocking (dilatancy) contribution. This may be stated:

$$\tau_{peak}=\sigma_n'\tan \phi_{peak}'$$

where $\phi_{peak}'>\phi_{crit}'$. However, use of a friction angle greater than the critical state value for design requires care. The peak strength will not be mobilized everywhere at the same time in a practical problem such as a foundation, slope or retaining wall. The critical state friction angle is not nearly as variable as the peak friction angle and hence it can be relied upon with confidence.[3][4][11]

Not recognizing the significance of dilatancy, Coulomb proposed that the shear strength of soil may be expressed as a combination of adhesion and friction components:[11]

$$\tau_f=c'+\sigma_f'\tan \phi ',$$

It is now known that the c' and ϕ' parameters in the last equation are not fundamental soil properties.[3][6][11][16] In particular, c' and ϕ' are different depending on the magnitude of effective stress.[6][16] According to Schofield (2006),[11] the longstanding use of c' in practice has led many engineers to wrongly believe that c' is a fundamental parameter. This assumption that c' and ϕ' are constant can lead to overestimation of peak strengths.[3][16]

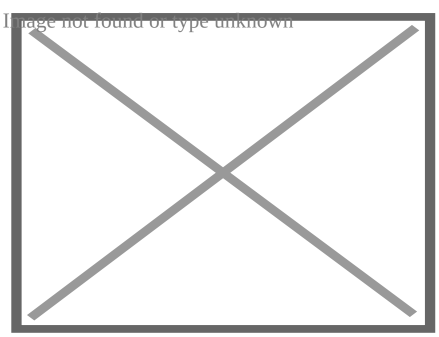
Structure, fabric, and chemistry

[edit]

In addition to the friction and interlocking (dilatancy) components of strength, the structure and fabric also play a significant role in the soil behavior. The structure and fabric include factors such as the spacing and arrangement of the solid particles or the amount and spatial distribution of pore water; in some cases cementitious material accumulates at particle-particle contacts. Mechanical behavior of soil is affected by the density of the particles and their structure or arrangement of the particles as well as the amount and spatial distribution of fluids present (e.g., water and air voids). Other factors include the electrical charge of the particles, chemistry of pore water, chemical bonds (i.e. cementation -particles connected through a solid substance such as recrystallized calcium carbonate) [1][16]

Drained and undrained shear

[edit]



Moist sand along the shoreline is originally densely packed by the draining water. Foot pressure on the sand causes it to dilate *(see: Reynolds dilatancy)*, drawing water from the surface into the pores.

The presence of nearly incompressible fluids such as water in the pore spaces affects the ability for the pores to dilate or contract.

If the pores are saturated with water, water must be sucked into the dilating pore spaces to fill the expanding pores (this phenomenon is visible at the beach when apparently dry spots form around feet that press into the wet sand).[*clarification needed*]

Similarly, for contractive soil, water must be squeezed out of the pore spaces to allow contraction to take place.

Dilation of the voids causes negative water pressures that draw fluid into the pores, and contraction of the voids causes positive pore pressures to push the water out of the pores. If the rate of shearing is very large compared to the rate that water can be sucked into or squeezed out of the dilating or contracting pore spaces, then the shearing is called *undrained shear*, if the shearing is slow enough that the water pressures are negligible, the shearing is called *drained shear*. During undrained shear, the water pressure u changes depending on volume change tendencies. From the effective stress equation, the change in u directly effects the effective stress by the equation:

$$\displaystyle \sigma '=\sigma -u\,$$

and the strength is very sensitive to the effective stress. It follows then that the undrained shear strength of a soil may be smaller or larger than the drained shear strength depending upon whether the soil is contractive or dilative.

Shear tests

[edit]

Strength parameters can be measured in the laboratory using direct shear test, triaxial shear test, simple shear test, fall cone test and (hand) shear vane test; there are numerous other devices and variations on these devices used in practice today. Tests conducted to characterize the strength and stiffness of the soils in the ground include the Cone penetration test and the Standard penetration test.

Other factors

[edit]

The stress–strain relationship of soils, and therefore the shearing strength, is affected by:[17]

1. *soil composition* (basic soil material): mineralogy, grain size and grain size distribution, shape of particles, pore fluid type and content, ions on grain and in pore fluid.
2. *state* (initial): Defined by the initial void ratio, effective normal stress and shear stress (stress history). State can be describd by terms such as: loose, dense, overconsolidated, normally consolidated, stiff, soft, contractive, dilative, etc.
3. *structure*: Refers to the arrangement of particles within the soil mass; the manner in which the particles are packed or distributed. Features such as layers, joints, fissures, slickensides, voids, pockets, cementation, etc., are part of the structure. Structure of soils is described by terms such as: undisturbed, disturbed, remolded, compacted, cemented;

flocculent, honey-combed, single-grained; flocculated, deflocculated; stratified, layered, laminated; isotropic and anisotropic.

4. *Loading conditions*: Effective stress path - drained, undrained, and type of loading - magnitude, rate (static, dynamic), and time history (monotonic, cyclic).

Applications

[edit]

Lateral earth pressure

[edit]
Main article: Lateral earth pressure

Lateral earth stress theory is used to estimate the amount of stress soil can exert perpendicular to gravity. This is the stress exerted on retaining walls. A lateral earth stress coefficient, K, is defined as the ratio of lateral (horizontal) effective stress to vertical effective stress for cohesionless soils (K=?'$_h$/?'$_v$). There are three coefficients: at-rest, active, and passive. At-rest stress is the lateral stress in the ground before any disturbance takes place. The active stress state is reached when a wall moves away from the soil under the influence of lateral stress, and results from shear failure due to reduction of lateral stress. The passive stress state is reached when a wall is pushed into the soil far enough to cause shear failure within the mass due to increase of lateral stress. There are many theories for estimating lateral earth stress; some are empirically based, and some are analytically derived.

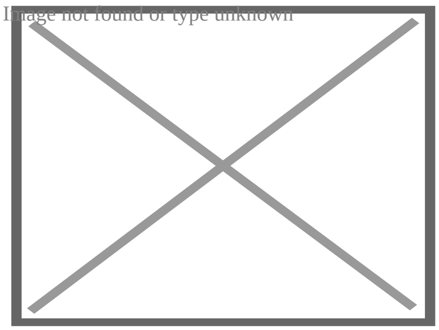
Bearing capacity

[edit]
Main article: Bearing capacity

The bearing capacity of soil is the average contact stress between a foundation and the soil which will cause shear failure in the soil. Allowable bearing stress is the bearing capacity divided by a factor of safety. Sometimes, on soft soil sites, large settlements may occur under loaded foundations without actual shear failure occurring; in such cases, the allowable bearing stress is determined with regard to the maximum allowable settlement. It is important during construction and design stage of a project to evaluate the subgrade strength. The California Bearing Ratio (CBR) test is commonly used to determine the suitability of a soil as a subgrade for design and construction. The field Plate Load Test is commonly used to predict the deformations and failure characteristics of the soil/subgrade and modulus of subgrade reaction (ks). The Modulus of subgrade reaction (ks) is used in foundation design, soil-structure interaction studies and design of highway pavements.[*citation needed*]

Slope stability

[edit]



Simple slope slip section

Main article: Slope stability

The field of slope stability encompasses the analysis of static and dynamic stability of slopes of earth and rock-fill dams, slopes of other types of embankments, excavated slopes, and natural slopes in soil and soft rock.[18]

As seen to the right, earthen slopes can develop a cut-spherical weakness zone. The probability of this happening can be calculated in advance using a simple 2-D circular analysis package.[19] A primary difficulty with analysis is locating the most-probable slip plane for any given situation.[20] Many landslides have been analyzed only after the fact. Landslides vs. Rock strength are two factors for consideration.

Recent developments

[edit]

A recent finding in soil mechanics is that soil deformation can be described as the behavior of a dynamical system. This approach to soil mechanics is referred to as Dynamical Systems based Soil Mechanics (DSSM). DSSM holds simply that soil deformation is a Poisson process in which particles move to their final position at random shear strains.

The basis of DSSM is that soils (including sands) can be sheared till they reach a steady-state condition at which, under conditions of constant strain-rate, there is no change in shear stress, effective confining stress, and void ratio. The steady-state was formally defined[21] by Steve J. Poulos Archived 2020-10-17 at the Wayback Machine an associate professor at the Soil Mechanics Department of Harvard University, who built off a hypothesis that Arthur Casagrande was formulating towards the end of his career. The steady state condition is not the same as the "critical state" condition. It differs from the critical state in that it specifies a statistically constant structure at the steady state. The steady-state values are also very slightly dependent on the strain-rate.

Many systems in nature reach steady states, and dynamical systems theory describes such systems. Soil shear can also be described as a dynamical system.[22][23] The physical basis of the soil shear dynamical system is a Poisson process in which particles move to the steady-state at random shear strains.[24] Joseph[25] generalized this—particles move to their final position (not just steady-state) at random shear-strains. Because of its origins in the steady state concept, DSSM is sometimes informally called "Harvard soil mechanics."

DSSM provides for very close fits to stress–strain curves, including for sands. Because it tracks conditions on the failure plane, it also provides close fits for the post failure region of sensitive clays and silts something that other theories are not able to do. Additionally DSSM explains key relationships in soil mechanics that to date have simply been taken for granted, for example, why normalized undrained peak shear strengths vary with the log of the overconsolidation ratio and why stress–strain curves normalize with the initial effective confining stress; and why in one-dimensional consolidation the void ratio must vary with the log of the effective vertical stress, why the end-of-primary curve is unique for static load increments, and why the ratio of the creep value C? to the compression index Cc must be approximately constant for a wide range of soils.[26]

See also

[edit]

- Critical state soil mechanics
- Earthquake engineering
- Engineering geology
- Geotechnical centrifuge modeling
- Geotechnical engineering
- Geotechnical engineering (Offshore)
- Geotechnics
- Hydrogeology, aquifer characteristics closely related to soil characteristics
- International Society for Soil Mechanics and Geotechnical Engineering
- Rock mechanics
- Slope stability analysis

References

[edit]

1. ^ ***a b c d e f g h*** Mitchell, J.K., and Soga, K. (2005) Fundamentals of soil behavior, Third edition, John Wiley and Sons, Inc., ISBN 978-0-471-46302-3
2. ^ ***a b c d e f*** *Santamarina, J.C., Klein, K.A., & Fam, M.A. (2001). Soils and Waves: Particulate Materials Behavior, Characterization and Process Monitoring. Wiley. ISBN 978-0-471-49058-6.*cite book: CS1 maint: multiple names: authors list (link).

3. ^ ***a b c d e f g h i j k l*** Powrie, W., Spon Press, 2004, *Soil Mechanics – 2nd ed* ISBN 0-415-31156-X
4. ^ ***a b c d e f*** A Guide to Soil Mechanics, Bolton, Malcolm, Macmillan Press, 1979. ISBN 0-333-18931-0
5. **^** *"Built Environment – Routledge". Routledge.com. Retrieved 2017-01-14.*
6. ^ ***a b c d e*** Lambe, T. William & Robert V. Whitman. *Soil Mechanics*. Wiley, 1991; p. 29. ISBN 978-0-471-51192-2
7. ^ ***a b c d*** *Guerriero V., Mazzoli S. (2021). "Theory of Effective Stress in Soil and Rock and Implications for Fracturing Processes: A Review". Geosciences.* ***11*** *(3): 119. Bibcode:2021Geosc..11..119G. doi:10.3390/geosciences11030119.*
8. **^** ASTM Standard Test Methods of Particle-Size Distribution (Gradation) of Soils using Sieve Analysis. http://www.astm.org/Standards/D6913.htm Archived 2011-08-10 at the Wayback Machine
9. **^** *"Classification of Soils for Engineering Purposes: Annual Book of ASTM Standards". D 2487-83.* ***04*** *(8). American Society for Testing and Materials. 1985: 395–408. Archived from the original on 2010-09-14. Retrieved 2010-08-31.* cite journal: Cite journal requires |journal= (help)
10. ^ ***a b*** Wood, David Muir, Soil Behavior and Critical State Soil Mechanics, Cambridge University Press, 1990, ISBN 0-521-33249-4
11. ^ ***a b c d e f g*** Disturbed soil properties and geotechnical design, Schofield, Andrew N., Thomas Telford, 2006. ISBN 0-7277-2982-9
12. **^** ASTM Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density. http://www.astm.org/Standards/D4254.htm Archived 2011-09-07 at the Wayback Machine
13. **^** *Ozhovan, M.I.; Dmitriev, I.E.; Batyukhnova, O.G. (1993). "Fractal structure of pores in clay soil". Atomic Energy.* ***74*** *(3): 241–243. doi:10.1007/BF00739059. S2CID 95352427.*
14. ^ ***a b*** Holtz, R.D, and Kovacs, W.D., 1981. An Introduction to Geotechnical Engineering. Prentice-Hall, Inc. page 448
15. **^** Terzaghi, K., 1943, *Theoretical Soil Mechanics*, John Wiley and Sons, New York
16. ^ ***a b c d*** Terzaghi, K., Peck, R.B., Mesri, G. (1996) Soil mechanics in Engineering Practice, Third Edition, John Wiley & Sons, Inc.,ISBN 0-471-08658-4
17. **^** Poulos, S. J. 1989. Advance Dam Engineering for Design, Construction, and Rehabilitation: Liquefaction Related Phenomena. Ed. Jansen, R.B, Van Nostrand Reinhold, pages 292–297.
18. **^** *Slope Stability (PDF). Engineer Manual. Vol. EM 1110-2-1902. United States Army Corps of Engineers. 3 Oct 2003. Archived (PDF) from the original on 2016-12-29. Retrieved 2017-01-18.*
19. **^** *"Slope Stability Calculator". Retrieved 2006-12-14.*
20. **^** *Chugh, A.K. (2002). "A method for locating critical slip surfaces in slope stability analysis: Discussion". Canadian Geotechnical Journal.* ***39*** *(3): 765–770. doi:10.1139/t02-042.*
21. **^** *Poulos, Steve J. (1981). "The Steady State of Deformation". Journal of Geotechnical Engineering.* ***107*** *(GT5): 553–562.*
22. **^** *Joseph, Paul G. (2009). "Constitutive Model of Soil Based on a Dynamical Systems Approach". Journal of Geotechnical and Geoenvironmental Engineering.* ***135*** *(8): 1155–1158. doi:10.1061/(asce)gt.1943-5606.0000001.*

23. **^** *Joseph, Paul G. (2010). "A Dynamical Systems Based Approach to Soil Shear". Géotechnique.* ***LX*** *(10): 807–812. Bibcode:2010Getq...60..807J. doi:10.1680/geot.9.p.001.*
24. **^** *Joseph, Paul G. (2012). "Physical Basis and Validation of a Constitutive Model for Soil Shear Derived from Micro-Structural Changes". International Journal of Geomechanics.* ***13*** *(4): 365–383. doi:10.1061/(asce)gm.1943-5622.0000209.*
25. **^** *Joseph, Paul G. (2014). "Generalised dynamical systems soil deformation model". Geotechnical Research.* ***1*** *(1): 32–42. Bibcode:2014GeotR...1...32J. doi: 10.1680/geores.14.00004.*
26. **^** *Joseph, Paul G. (2017). Dynamical Systems-Based Soil Mechanics (first ed.). CRC Press/Balkema. p. 138. ISBN 9781138723221. Archived from the original on 2018-03-24. Retrieved 2017-05-14.*

External links

[edit]

- Image not found or type unknown Media related to Soil mechanics at Wikimedia Commons

- v
- t
- e

Soil science

- History
- Index

Main fields

- Pedology
- Edaphology
- Soil biology
- Soil microbiology
- Soil zoology
- Soil ecology
- Soil physics
- Soil mechanics
- Soil chemistry
- Environmental soil science
- Agricultural soil science

Image not found or type unknown

Soil topics

- Soil
- Pedosphere
  - Soil morphology
  - Pedodiversity
  - Soil formation
- Soil erosion
- Soil contamination
- Soil retrogression and degradation
- Soil compaction
  - Soil compaction (agriculture)
- Soil sealing
- Soil salinity
  - Alkali soil
- Soil pH
  - Soil acidification
- Soil health
- Soil life
- Soil biodiversity
- Soil quality
- Soil value
- Soil fertility
- Soil resilience
- Soil color
- Soil texture
- Soil structure
  - Pore space in soil
  - Pore water pressure
- Soil crust
- Soil horizon
- Soil biomantle
- Soil carbon
- Soil gas
  - Soil respiration
- Soil organic matter
- Soil moisture
  - Soil water (retention)

- v
- t
- e

Soil classification

World Reference Base for Soil Resources (1998–)	◦ Acrisols ◦ Alisols ◦ Andosols ◦ Anthrosols ◦ Arenosols ◦ Calcisols ◦ Cambisols ◦ Chernozem ◦ Cryosols ◦ Durisols ◦ Ferralsols ◦ Fluvisols ◦ Gleysols ◦ Gypsisols ◦ Histosol ◦ Kastanozems ◦ Leptosols ◦ Lixisols ◦ Luvisols ◦ Nitisols ◦ Phaeozems ◦ Planosols ◦ Plinthosols ◦ Podzols ◦ Regosols ◦ Retisols ◦ Solonchaks ◦ Solonetz ◦ Stagnosol ◦ Technosols ◦ Umbrisols ◦ Vertisols
USDA soil taxonomy	◦ Alfisols ◦ Andisols ◦ Aridisols ◦ Entisols ◦ Gelisols ◦ Histosols ◦ Inceptisols ◦ Mollisols

Applications	○ Soil conservation ○ Soil management ○ Soil guideline value ○ Soil survey ○ Soil test ○ Soil governance ○ Soil value ○ Soil salinity control ○ Erosion control ○ Agroecology ○ Liming (soil)
Related fields	○ Geology ○ Geochemistry ○ Petrology ○ Geomorphology ○ Geotechnical engineering ○ Hydrology ○ Hydrogeology ○ Biogeography ○ Earth materials ○ Archaeology ○ Agricultural science ○ Agrology
Societies, Initiatives	○ Australian Society of Soil Science Incorporated ○ Canadian Society of Soil Science ○ Central Soil Salinity Research Institute (India) ○ German Soil Science Society ○ Indian Institute of Soil Science ○ International Union of Soil Sciences ○ International Year of Soil ○ National Society of Consulting Soil Scientists (US) ○ OPAL Soil Centre (UK) ○ Soil Science Society of Poland ○ Soil and Water Conservation Society (US) ○ Soil Science Society of America ○ World Congress of Soil Science

Scientific journals	○ *Acta Agriculturae Scandinavica B* ○ *Journal of Soil and Water Conservation* ○ *Plant and Soil* ○ *Pochvovedenie* ○ *Soil Research* ○ *Soil Science Society of America Journal*
See also	○ Land use ○ Land conversion ○ Land management ○ Vegetation ○ Infiltration (hydrology) ○ Groundwater ○ Crust (geology) ○ Impervious surface/Surface runoff ○ Petrichor

- Image not found or type unknown Wikipedia:WikiProject Soil
- Image not found or type unknown Category soil
- Category soil science
- Image not found or type unknown List of soil scientists

- v
- t
- e

Geotechnical engineering

Offshore geotechnical engineering

Investigation and instrumentation

Field (*in situ*)

- Image not found or type unknown Core drill
- Image not found or type unknown Cone penetration test
- Image not found or type unknown Geo-electrical sounding
- Image not found or type unknown Permeability test
- Image not found or type unknown Load test
  - Static
  - Dynamic
  - Statnamic
- Image not found or type unknown Pore pressure measurement
  - Piezometer
  - Well
- Image not found or type unknown Ram sounding
- Image not found or type unknown Rock control drilling
- Image not found or type unknown Rotary-pressure sounding
- Image not found or type unknown Rotary weight sounding
- Image not found or type unknown Sample series
- Image not found or type unknown Screw plate test
- Deformation monitoring
  - Image not found or type unknown Inclinometer
  - Image not found or type unknown Settlement recordings
- Image not found or type unknown Shear vane test
- Image not found or type unknown Simple sounding
- Image not found or type unknown Standard penetration test
- Image not found or type unknown Total sounding
- Image not found or type unknown Trial pit
- Image not found or type unknown Visible bedrock
- Nuclear densometer test
- Exploration geophysics
- Crosshole sonic logging

Soil

- Types
  - Clay
  - Silt
  - Sand
  - Gravel
  - Peat
  - Loam
  - Loess
- Properties
  - Hydraulic conductivity
  - Water content
  - Void ratio
  - Bulk density
  - Thixotropy
  - Reynolds' dilatancy
  - Angle of repose
  - Friction angle
  - Cohesion
  - Porosity
  - Permeability
  - Specific storage
  - Shear strength
  - Sensitivity

Structures (Interaction)	Natural features	○ Topography ○ Vegetation ○ Terrain ○ Topsoil ○ Water table ○ Bedrock ○ Subgrade ○ Subsoil

	Earthworks	○ Shoring structures
		    ○ Retaining walls
		    ○ Gabion
		    ○ Ground freezing
		    ○ Mechanically stabilized earth
		    ○ Pressure grouting
		    ○ Slurry wall
		    ○ Soil nailing
		    ○ Tieback
		○ Land development
		○ Landfill
		○ Excavation
		○ Trench
		○ Embankment
		○ Cut
		○ Causeway
		○ Terracing
		○ Cut-and-cover
		○ Cut and fill
		○ Fill dirt
		○ Grading
		○ Land reclamation
		○ Track bed
		○ Erosion control
		○ Earth structure
		○ Expanded clay aggregate
		○ Crushed stone
		○ Geosynthetics
		    ○ Geotextile
		    ○ Geomembrane
		    ○ Geosynthetic clay liner
		    ○ Cellular confinement
		○ Infiltration

	Foundations	○ Shallow ○ Deep

Mechanics	Forces	○ Effective stress ○ Pore water pressure ○ Lateral earth pressure ○ Overburden pressure ○ Preconsolidation pressure

	Phenomena/ problems	○ Permafrost
		○ Frost heaving
		○ Consolidation
		○ Compaction
		○ Earthquake
		    ○ Response spectrum
		    ○ Seismic hazard
		    ○ Shear wave
		○ Landslide analysis
		    ○ Stability analysis
		    ○ Mitigation
		    ○ Classification
		    ○ Sliding criterion
		    ○ Slab stabilisation
		○ Bearing capacity * Stress distribution in soil

Numerical analysis software	○ SEEP2D ○ STABL ○ SVFlux ○ SVSlope ○ UTEXAS ○ Plaxis	

Related fields

- Geology
- Geochemistry
- Petrology
- Earthquake engineering
- Geomorphology
- Soil science
- Hydrology
- Hydrogeology
- Biogeography
- Earth materials
- Archaeology
- Agricultural science
  - Agrology

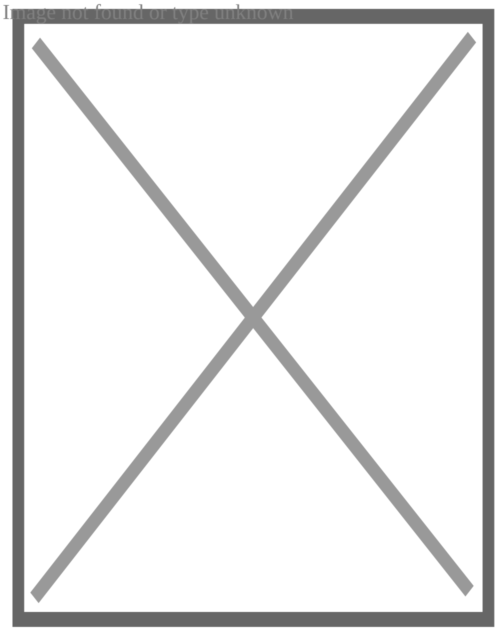
Authority control databases: National

- Germany
- United States
- France
- BnF data
- Japan
- Czech Republic
- Israel

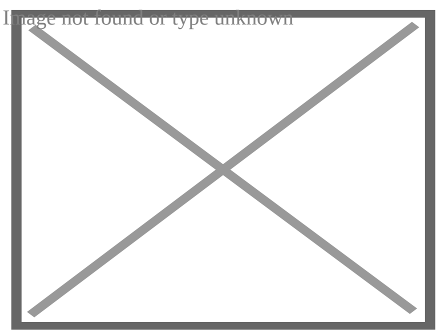
Image not found or type unknown

Edit this at Wikidata

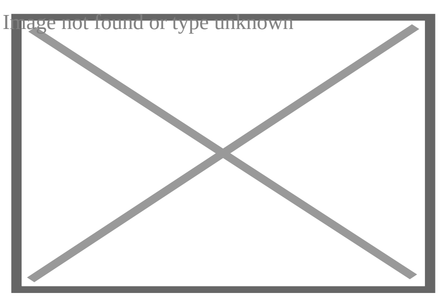
About geotechnical engineering



Boston's Big Dig presented geotechnical challenges in an urban environment.



Precast concrete retaining wall



A typical cross-section of a slope used in two-dimensional analyzes.

Geotechnical engineering, also known as **geotechnics**, is the branch of civil engineering concerned with the engineering behavior of earth materials. It uses the principles of soil mechanics and rock mechanics to solve its engineering problems. It also relies on knowledge of geology, hydrology, geophysics, and other related sciences.

Geotechnical engineering has applications in military engineering, mining engineering, petroleum engineering, coastal engineering, and offshore construction. The fields of geotechnical engineering and engineering geology have overlapping knowledge areas. However, while geotechnical engineering is a specialty of civil engineering, engineering geology is a specialty of geology.

History

[edit]

Humans have historically used soil as a material for flood control, irrigation purposes, burial sites, building foundations, and construction materials for buildings. Dykes, dams, and canals dating back to at least 2000 BCE—found in parts of ancient Egypt, ancient Mesopotamia, the Fertile Crescent, and the early settlements of Mohenjo Daro and Harappa in the Indus valley—provide evidence for early activities linked to irrigation and flood control. As cities expanded, structures were erected and supported by formalized foundations. The ancient Greeks notably constructed pad footings and strip-and-raft foundations. Until the 18th century, however, no theoretical basis for soil design had been developed, and the discipline was more of an art than a science, relying on experience.[1]

Several foundation-related engineering problems, such as the Leaning Tower of Pisa, prompted scientists to begin taking a more scientific-based approach to examining the subsurface. The earliest advances occurred in the development of earth pressure theories for the construction of retaining walls. Henri Gautier, a French royal engineer, recognized the "natural slope" of different soils in 1717, an idea later known as the soil's angle of repose. Around the same time, a rudimentary soil classification system was also developed based on a material's unit weight, which is no longer considered a good indication of soil type.[1][2]

The application of the principles of mechanics to soils was documented as early as 1773 when Charles Coulomb, a physicist and engineer, developed improved methods to determine the earth pressures against military ramparts. Coulomb observed that, at failure, a distinct slip plane would form behind a sliding retaining wall and suggested that the maximum shear stress on the slip plane, for design purposes, was the sum of the soil cohesion, c, and friction $\sigma \tan(\phi)$, where σ is the normal stress on the slip plane and ϕ is the friction angle of the soil. By combining Coulomb's theory with Christian Otto Mohr's 2D stress state, the theory became known as Mohr-Coulomb theory. Although it is now recognized that precise determination of cohesion is impossible because c is not a fundamental soil property, the Mohr-Coulomb theory is still used in practice today.[3]

In the 19th century, Henry Darcy developed what is now known as Darcy's Law, describing the flow of fluids in a porous media. Joseph Boussinesq, a mathematician and physicist, developed theories of stress distribution in elastic solids that proved useful for estimating stresses at depth in the ground. William Rankine, an engineer and physicist, developed an alternative to Coulomb's earth pressure theory. Albert Atterberg developed the clay consistency indices that are still used today for soil classification.[1][2] In 1885, Osborne Reynolds recognized that shearing causes volumetric dilation of dense materials and contraction of loose granular materials.

Modern geotechnical engineering is said to have begun in 1925 with the publication of *Erdbaumechanik* by Karl von Terzaghi, a mechanical engineer and geologist. Considered by many to be the father of modern soil mechanics and geotechnical engineering, Terzaghi developed the principle of effective stress, and demonstrated that the shear strength of soil is controlled by effective stress.[4] Terzaghi also developed the framework for theories of bearing capacity of foundations, and the theory for prediction of the rate of settlement of clay layers due to consolidation.[1][3][5] Afterwards, Maurice Biot fully developed the three-dimensional soil consolidation theory, extending the one-dimensional model previously developed by Terzaghi to more general hypotheses and introducing the set of basic equations of Poroelasticity.

In his 1948 book, Donald Taylor recognized that the interlocking and dilation of densely packed particles contributed to the peak strength of the soil. Roscoe, Schofield, and Wroth, with the publication of *On the Yielding of Soils* in 1958, established the interrelationships between the volume change behavior (dilation, contraction, and consolidation) and shearing behavior with the theory of plasticity using critical state soil mechanics. Critical state soil mechanics is the basis for many contemporary advanced constitutive models describing the behavior of soil.[6]

In 1960, Alec Skempton carried out an extensive review of the available formulations and experimental data in the literature about the effective stress validity in soil, concrete, and rock in order to reject some of these expressions, as well as clarify what expressions were appropriate according to several working hypotheses, such as stress-strain or strength behavior, saturated or non-saturated media, and rock, concrete or soil behavior.

Roles

[edit]

Geotechnical investigation

[edit]
Main article: Geotechnical investigation

Geotechnical engineers investigate and determine the properties of subsurface conditions and materials. They also design corresponding earthworks and retaining structures, tunnels, and structure foundations, and may supervise and evaluate sites, which may further involve site monitoring as well as the risk assessment and mitigation of natural hazards.[7][8]

Geotechnical engineers and engineering geologists perform geotechnical investigations to obtain information on the physical properties of soil and rock underlying and adjacent to a site to design earthworks and foundations for proposed structures and for the repair of distress to earthworks and structures caused by subsurface conditions. Geotechnical investigations involve surface and subsurface exploration of a site, often including subsurface sampling and laboratory testing of retrieved soil samples. Sometimes, geophysical methods are also used to obtain data, which include measurement of seismic waves (pressure, shear, and Rayleigh waves), surface-wave methods and downhole methods, and electromagnetic surveys (magnetometer, resistivity, and ground-penetrating radar). Electrical tomography can be used to survey soil and rock properties and existing underground infrastructure in construction projects.[9]

Surface exploration can include on-foot surveys, geologic mapping, geophysical methods, and photogrammetry. Geologic mapping and interpretation of geomorphology are typically completed in consultation with a geologist or engineering geologist. Subsurface exploration usually involves in-situ testing (for example, the standard penetration test and cone penetration test). The digging of test pits and trenching (particularly for locating faults and slide planes) may also be used to learn about soil conditions at depth. Large-diameter borings are rarely used due to safety concerns and expense. Still, they are sometimes used to allow a geologist or engineer to be lowered into the borehole for direct visual and manual examination of the soil and rock stratigraphy.

Various soil samplers exist to meet the needs of different engineering projects. The standard penetration test, which uses a thick-walled split spoon sampler, is the most common way to collect disturbed samples. Piston samplers, employing a thin-walled tube, are most commonly used to collect less disturbed samples. More advanced methods, such as the Sherbrooke block sampler, are superior but expensive. Coring frozen ground provides high-quality undisturbed samples from ground conditions, such as fill, sand, moraine, and rock fracture zones.[10]

Geotechnical centrifuge modeling is another method of testing physical-scale models of geotechnical problems. The use of a centrifuge enhances the similarity of the scale model tests involving soil because soil's strength and stiffness are susceptible to the confining pressure. The centrifugal acceleration allows a researcher to obtain large (prototype-scale) stresses in small physical models.

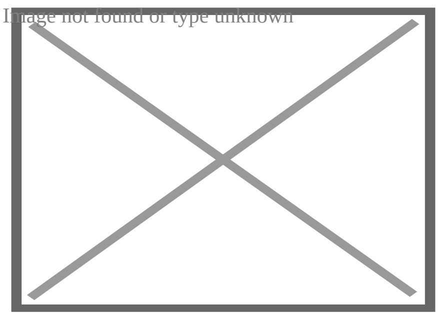
Foundation design

[edit]
Main article: Foundation (engineering)

The foundation of a structure's infrastructure transmits loads from the structure to the earth. Geotechnical engineers design foundations based on the load characteristics of the structure and the properties of the soils and bedrock at the site. Generally, geotechnical engineers first estimate the magnitude and location of loads to be supported before developing an investigation plan to explore the subsurface and determine the necessary soil parameters through field and lab testing. Following this, they may begin the design of an engineering foundation. The primary considerations for a geotechnical engineer in foundation design are bearing capacity, settlement, and ground movement beneath the foundations.[11]

Earthworks

[edit]



A compactor/roller operated by U.S. Navy Seabees

See also: Earthworks (engineering)

Geotechnical engineers are also involved in the planning and execution of earthworks, which include ground improvement,[11] slope stabilization, and slope stability analysis.

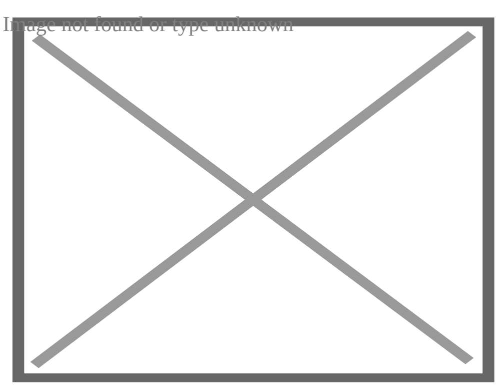
Ground improvement

[edit]

Various geotechnical engineering methods can be used for ground improvement, including reinforcement geosynthetics such as geocells and geogrids, which disperse loads over a larger area, increasing the soil's load-bearing capacity. Through these methods, geotechnical engineers can reduce direct and long-term costs.[12]

Slope stabilization

[edit]



Simple slope slip section.

Main article: Slope stability

Geotechnical engineers can analyze and improve slope stability using engineering methods. Slope stability is determined by the balance of shear stress and shear strength. A previously stable slope may be initially affected by various factors, making it unstable. Nonetheless, geotechnical engineers can design and implement engineered slopes to increase stability.

Slope stability analysis

[edit]
Main article: Slope stability analysis

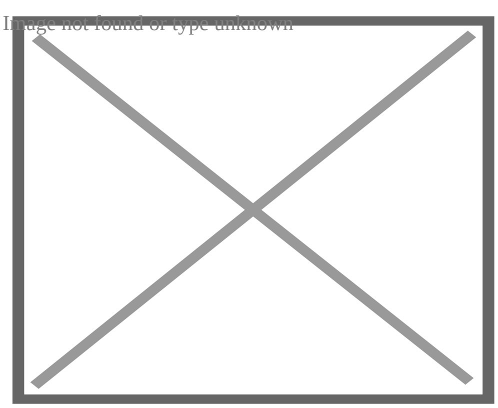
Stability analysis is needed to design engineered slopes and estimate the risk of slope failure in natural or designed slopes by determining the conditions under which the topmost mass of soil will slip relative to the base of soil and lead to slope failure.[13] If the interface between the mass and the base of a slope has a complex geometry, slope stability analysis is difficult and numerical solution methods are required. Typically, the interface's exact geometry is unknown, and a simplified interface geometry is assumed. Finite slopes require three-dimensional models to be analyzed, so most slopes are analyzed assuming that they are infinitely wide and can be represented by two-dimensional models.

Sub-disciplines

[edit]

Geosynthetics

[edit]
Main article: Geosynthetics



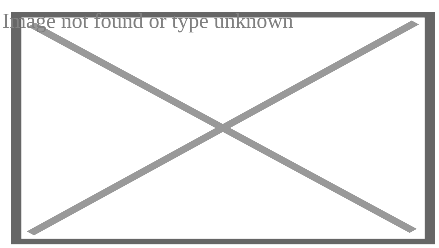
A collage of geosynthetic products.

Geosynthetics are a type of plastic polymer products used in geotechnical engineering that improve engineering performance while reducing costs. This includes geotextiles, geogrids, geomembranes, geocells, and geocomposites. The synthetic nature of the products make them suitable for use in the ground where high levels of durability are required. Their main functions include drainage, filtration, reinforcement, separation, and containment.

Geosynthetics are available in a wide range of forms and materials, each to suit a slightly different end-use, although they are frequently used together. Some reinforcement geosynthetics, such as geogrids and more recently, cellular confinement systems, have shown to improve bearing capacity, modulus factors and soil stiffness and strength.[14] These products have a wide range of applications and are currently used in many civil and geotechnical engineering applications including roads, airfields, railroads, embankments, piled embankments, retaining structures, reservoirs, canals, dams, landfills, bank protection and coastal engineering.[15]

Offshore

[edit]
Main article: Offshore geotechnical engineering



Platforms offshore Mexico.

Offshore (or *marine*) *geotechnical engineering* is concerned with foundation design for human-made structures in the sea, away from the coastline (in opposition to *onshore* or *nearshore* engineering). Oil platforms, artificial islands and submarine pipelines are examples of such structures.[16]

There are a number of significant differences between onshore and offshore geotechnical engineering.[16][17] Notably, site investigation and ground improvement on the seabed are more expensive; the offshore structures are exposed to a wider range of geohazards; and the environmental and financial consequences are higher in case of failure. Offshore structures are exposed to various environmental loads, notably wind, waves and currents. These phenomena may affect the integrity or the serviceability of the structure and its foundation during its operational lifespan and need to be taken into account in offshore design.

In subsea geotechnical engineering, seabed materials are considered a two-phase material composed of rock or mineral particles and water.[18][19] Structures may be fixed in place in the seabed—as is the case for piers, jetties and fixed-bottom wind turbines—or may comprise a floating structure that remains roughly fixed relative to its geotechnical anchor point. Undersea mooring of human-engineered floating structures include a large number of offshore oil and gas platforms and, since 2008, a few floating wind turbines. Two common types of engineered design for anchoring floating structures include tension-leg and catenary loose mooring systems.[20]

Observational method

[edit]

First proposed by Karl Terzaghi and later discussed in a paper by Ralph B. Peck, the observational method is a managed process of construction control, monitoring, and review, which enables modifications to be incorporated during and after construction. The method aims to achieve a greater overall economy without compromising safety by creating designs based on the most probable conditions rather than the most unfavorable.[21] Using the observational method, gaps in available information are filled by measurements and investigation, which aid in assessing the behavior of the structure during construction, which in turn can be modified per the findings. The method was described by Peck as "learn-as-you-go".[22]

The observational method may be described as follows:[22]

1. General exploration sufficient to establish the rough nature, pattern, and properties of deposits.
2. Assessment of the most probable conditions and the most unfavorable conceivable deviations.
3. Creating the design based on a working hypothesis of behavior anticipated under the most probable conditions.
4. Selection of quantities to be observed as construction proceeds and calculating their anticipated values based on the working hypothesis under the most unfavorable conditions.
5. Selection, in advance, of a course of action or design modification for every foreseeable significant deviation of the observational findings from those predicted.
6. Measurement of quantities and evaluation of actual conditions.
7. Design modification per actual conditions

The observational method is suitable for construction that has already begun when an unexpected development occurs or when a failure or accident looms or has already happened. It is unsuitable for projects whose design cannot be altered during construction.[22]

See also

[edit]

- icon Image not found or type unknown Engineering portal

- Civil engineering
- Deep Foundations Institute
- Earthquake engineering
- Earth structure
- Effective stress
- Engineering geology
- Geological Engineering
- Geoprofessions
- Hydrogeology
- International Society for Soil Mechanics and Geotechnical Engineering
- Karl von Terzaghi
- Land reclamation
- Landfill
- Mechanically stabilized earth
- Offshore geotechnical engineering
- Rock mass classifications
- Sediment control
- Seismology
- Soil mechanics
- Soil physics
- Soil science

Notes

[edit]

1. ^ ***a b c d*** *Das, Braja (2006). Principles of Geotechnical Engineering. Thomson Learning.*
2. ^ ***a b*** *Budhu, Muni (2007). Soil Mechanics and Foundations. John Wiley & Sons, Inc. ISBN 978-0-471-43117-6.*
3. ^ ***a b*** Disturbed soil properties and geotechnical design, Schofield, Andrew N., Thomas Telford, 2006. ISBN 0-7277-2982-9
4. **^** *Guerriero V., Mazzoli S. (2021). "Theory of Effective Stress in Soil and Rock and Implications for Fracturing Processes: A Review". Geosciences.* ***11*** *(3): 119. Bibcode:2021Geosc..11..119G. doi:10.3390/geosciences11030119.*
5. **^** Soil Mechanics, Lambe, T.William and Whitman, Robert V., Massachusetts Institute of Technology, John Wiley & Sons., 1969. ISBN 0-471-51192-7
6. **^** Soil Behavior and Critical State Soil Mechanics, Wood, David Muir, Cambridge University Press, 1990. ISBN 0-521-33782-8
7. **^** Terzaghi, K., Peck, R.B. and Mesri, G. (1996), *Soil Mechanics in Engineering Practice* 3rd Ed., John Wiley & Sons, Inc. ISBN 0-471-08658-4
8. **^** Holtz, R. and Kovacs, W. (1981), *An Introduction to Geotechnical Engineering*, Prentice-Hall, Inc. ISBN 0-13-484394-0

9. **^** Deep Scan Tech (2023): Deep Scan Tech uncovers hidden structures at the site of Denmark's tallest building.
10. **^** *"Geofrost Coring". GEOFROST. Retrieved 20 November 2020.*
11. ^ ***a b*** *Han, Jie (2015). Principles and Practice of Ground Improvement. Wiley. ISBN 9781118421307.*
12. **^** *RAJU, V. R. (2010). Ground Improvement Technologies and Case Histories. Singapore: Research Publishing Services. p. 809. ISBN 978-981-08-3124-0. Ground Improvement – Principles And Applications In Asia.*
13. **^** *Pariseau, William G. (2011). Design analysis in rock mechanics. CRC Press.*
14. **^** Hegde, A.M. and Palsule P.S. (2020), Performance of Geosynthetics Reinforced Subgrade Subjected to Repeated Vehicle Loads: Experimental and Numerical Studies. Front. Built Environ. 6:15. https://www.frontiersin.org/articles/10.3389/fbuil.2020.00015/full.
15. **^** *Koerner, Robert M. (2012). Designing with Geosynthetics (6th Edition, Vol. 1 ed.). Xlibris. ISBN 9781462882892.*
16. ^ ***a b*** Dean, E.T.R. (2010). Offshore Geotechnical Engineering – Principles and Practice. Thomas Telford, Reston, VA, 520 p.
17. **^** Randolph, M. and Gourvenec, S., 2011. Offshore geotechnical engineering. Spon Press, N.Y., 550 p.
18. **^** Das, B.M., 2010. Principles of geotechnical engineering. Cengage Learning, Stamford, 666 p.
19. **^** Atkinson, J., 2007. The mechanics of soils and foundations. Taylor & Francis, N.Y., 442 p.
20. **^** Floating Offshore Wind Turbines: Responses in a Sea state – Pareto Optimal Designs and Economic Assessment, P. Sclavounos et al., October 2007.
21. **^** Nicholson, D, Tse, C and Penny, C. (1999). The Observational Method in ground engineering – principles and applications. Report 185, CIRIA, London.
22. ^ ***a b c*** Peck, R.B (1969). Advantages and limitations of the observational method in applied soil mechanics, Geotechnique, 19, No. 1, pp. 171-187.

References

[edit]

- Bates and Jackson, 1980, Glossary of Geology: American Geological Institute.
- Krynine and Judd, 1957, Principles of Engineering Geology and Geotechnics: McGraw-Hill, New York.
- Ventura, Pierfranco, 2019, Fondazioni, Volume 1, Modellazioni statiche e sismiche, Hoepli, Milano

- Holtz, R. and Kovacs, W. (1981), *An Introduction to Geotechnical Engineering*, Prentice-Hall, Inc. ISBN 0-13-484394-0
- Bowles, J. (1988), *Foundation Analysis and Design*, McGraw-Hill Publishing Company. ISBN 0-07-006776-7
- Cedergren, Harry R. (1977), *Seepage, Drainage, and Flow Nets*, Wiley. ISBN 0-471-14179-8
- Kramer, Steven L. (1996), *Geotechnical Earthquake Engineering*, Prentice-Hall, Inc. ISBN 0-13-374943-6
- Freeze, R.A. & Cherry, J.A., (1979), *Groundwater*, Prentice-Hall. ISBN 0-13-365312-9
- Lunne, T. & Long, M.,(2006), *Review of long seabed samplers and criteria for new sampler design*, Marine Geology, Vol 226, p. 145–165
- Mitchell, James K. & Soga, K. (2005), *Fundamentals of Soil Behavior* 3rd ed., John Wiley & Sons, Inc. ISBN 978-0-471-46302-3
- Rajapakse, Ruwan., (2005), "Pile Design and Construction", 2005. ISBN 0-9728657-1-3
- Fang, H.-Y. and Daniels, J. (2005) *Introductory Geotechnical Engineering : an environmental perspective*, Taylor & Francis. ISBN 0-415-30402-4
- NAVFAC (Naval Facilities Engineering Command) (1986) *Design Manual 7.01, Soil Mechanics*, US Government Printing Office
- NAVFAC (Naval Facilities Engineering Command) (1986) *Design Manual 7.02, Foundations and Earth Structures*, US Government Printing Office
- NAVFAC (Naval Facilities Engineering Command) (1983) *Design Manual 7.03, Soil Dynamics, Deep Stabilization and Special Geotechnical Construction*, US Government Printing Office
- Terzaghi, K., Peck, R.B. and Mesri, G. (1996), *Soil Mechanics in Engineering Practice* 3rd Ed., John Wiley & Sons, Inc. ISBN 0-471-08658-4
- Santamarina, J.C., Klein, K.A., & Fam, M.A. (2001), "Soils and Waves: Particulate Materials Behavior, Characterization and Process Monitoring", Wiley, ISBN 978-0-471-49058-6
- Firuziaan, M. and Estorff, O., (2002), "Simulation of the Dynamic Behavior of Bedding-Foundation-Soil in the Time Domain", Springer Verlag.

External links

[edit]

- Worldwide Geotechnical Literature Database

- v
- t
- e

Engineering

- History
- Outline
- List of engineering branches

Civil

- Architectural
- Coastal
- Construction
- Earthquake
- Ecological
- Environmental
  - Sanitary
- Geological
- Geotechnical
- Hydraulic
- Mining
- Municipal/urban
- Offshore
- River
- Structural
- Transportation
  - Traffic
  - Railway

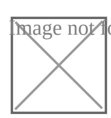
Mechanical

- Acoustic
- Aerospace
- Automotive
- Biomechanical
- Energy
- Manufacturing
- Marine
- Naval architecture
- Railway
- Sports
- Thermal
- Tribology

Specialties and interdisciplinarity

Electrical

- Broadcast
  - outline
- Control
- Electromechanics
- Electronics
- Microwaves
- Optical
- Power
- Radio-frequency
- Signal processing
- Telecommunications



- Biochemical/bioprocess

Engineering education	○ Bachelor of Engineering ○ Bachelor of Science ○ Master's degree ○ Doctorate ○ Graduate certificate ○ Engineer's degree ○ Licensed engineer
Related topics	○ Engineer

Glossaries	○ Engineering
	  ○ A–L
	  ○ M–Z
	○ Aerospace engineering
	○ Civil engineering
	○ Electrical and electronics engineering
	○ Mechanical engineering
	○ Structural engineering

Other

- Agricultural
- Audio
- Automation
- Biomedical
    - Bioinformatics
    - Clinical
    - Health technology
    - Pharmaceutical
    - Rehabilitation
- Building services
    - MEP
- Design
- Explosives
- Facilities
- Fire
- Forensic
- Climate
- Geomatics
- Graphics
- Industrial
- Information
- Instrumentation
    - Instrumentation and control
- Logistics
- Management
- Mathematics
- Mechatronics
- Military
- Nuclear
- Ontology
- Packaging
- Physics
- Privacy
- Safety
- Security
- Survey
- Sustainability
- Systems
- Textile

- Image not found or type unknown **Category**
- Image not found or type unknown **Commons**
- Image not found or type unknown **Wikiproject**
- Image not found or type unknown **Portal**

- v
- t
- e

Soil science

- History
- Index

Main fields

- Pedology
- Edaphology
- Soil biology
- Soil microbiology
- Soil zoology
- Soil ecology
- Soil physics
- Soil mechanics
- Soil chemistry
- Environmental soil science
- Agricultural soil science

Image not found or type unknown

Soil topics

- Soil
- Pedosphere
  - Soil morphology
  - Pedodiversity
  - Soil formation
- Soil erosion
- Soil contamination
- Soil retrogression and degradation
- Soil compaction
  - Soil compaction (agriculture)
- Soil sealing
- Soil salinity
  - Alkali soil
- Soil pH
  - Soil acidification
- Soil health
- Soil life
- Soil biodiversity
- Soil quality
- Soil value
- Soil fertility
- Soil resilience
- Soil color
- Soil texture
- Soil structure
  - Pore space in soil
  - Pore water pressure
- Soil crust
- Soil horizon
- Soil biomantle
- Soil carbon
- Soil gas
  - Soil respiration
- Soil organic matter
- Soil moisture
  - Soil water (retention)

Soil classification

World Reference Base for Soil Resources (1998–)	Acrisols Alisols Andosols Anthrosols Arenosols Calcisols Cambisols Chernozem Cryosols Durisols Ferralsols Fluvisols Gleysols Gypsisols Histosol Kastanozems Leptosols Lixisols Luvisols Nitisols Phaeozems Planosols Plinthosols Podzols Regosols Retisols Solonchaks Solonetz Stagnosol Technosols Umbrisols Vertisols
USDA soil taxonomy	Alfisols Andisols Aridisols Entisols Gelisols Histosols Inceptisols Mollisols

Applications	○ Soil conservation ○ Soil management ○ Soil guideline value ○ Soil survey ○ Soil test ○ Soil governance ○ Soil value ○ Soil salinity control ○ Erosion control ○ Agroecology ○ Liming (soil)
Related fields	○ Geology ○ Geochemistry ○ Petrology ○ Geomorphology ○ Geotechnical engineering ○ Hydrology ○ Hydrogeology ○ Biogeography ○ Earth materials ○ Archaeology ○ Agricultural science ○ Agrology
Societies, Initiatives	○ Australian Society of Soil Science Incorporated ○ Canadian Society of Soil Science ○ Central Soil Salinity Research Institute (India) ○ German Soil Science Society ○ Indian Institute of Soil Science ○ International Union of Soil Sciences ○ International Year of Soil ○ National Society of Consulting Soil Scientists (US) ○ OPAL Soil Centre (UK) ○ Soil Science Society of Poland ○ Soil and Water Conservation Society (US) ○ Soil Science Society of America ○ World Congress of Soil Science

Scientific journals

- *Acta Agriculturae Scandinavica B*
- *Journal of Soil and Water Conservation*
- *Plant and Soil*
- *Pochvovedenie*
- *Soil Research*
- *Soil Science Society of America Journal*

See also

- Land use
- Land conversion
- Land management
- Vegetation
- Infiltration (hydrology)
- Groundwater
- Crust (geology)
- Impervious surface/Surface runoff
- Petrichor

- Image not found or type unknown Wikipedia:WikiProject Soil
- Image not found or type unknown Category soil
- Category soil science
- Image not found or type unknown List of soil scientists

- v
- t
- e

Geotechnical engineering

Offshore geotechnical engineering

Investigation and instrumentation

Field (*in situ*)

- Core drill
- Cone penetration test
- Geo-electrical sounding
- Permeability test
- Load test
  - Static
  - Dynamic
  - Statnamic
- Pore pressure measurement
  - Piezometer
  - Well
- Ram sounding
- Rock control drilling
- Rotary-pressure sounding
- Rotary weight sounding
- Sample series
- Screw plate test
- Deformation monitoring
  - Inclinometer
  - Settlement recordings
- Shear vane test
- Simple sounding
- Standard penetration test
- Total sounding
- Trial pit
- Visible bedrock
- Nuclear densometer test
- Exploration geophysics
- Crosshole sonic logging

Soil

- Types
  - Clay
  - Silt
  - Sand
  - Gravel
  - Peat
  - Loam
  - Loess
- Properties
  - Hydraulic conductivity
  - Water content
  - Void ratio
  - Bulk density
  - Thixotropy
  - Reynolds' dilatancy
  - Angle of repose
  - Friction angle
  - Cohesion
  - Porosity
  - Permeability
  - Specific storage
  - Shear strength
  - Sensitivity

Structures (Interaction)

Natural features

- Topography
- Vegetation
- Terrain
- Topsoil
- Water table
- Bedrock
- Subgrade
- Subsoil

Earthworks

- Shoring structures
    - Retaining walls
    - Gabion
    - Ground freezing
    - Mechanically stabilized earth
    - Pressure grouting
    - Slurry wall
    - Soil nailing
    - Tieback
- Land development
- Landfill
- Excavation
- Trench
- Embankment
- Cut
- Causeway
- Terracing
- Cut-and-cover
- Cut and fill
- Fill dirt
- Grading
- Land reclamation
- Track bed
- Erosion control
- Earth structure
- Expanded clay aggregate
- Crushed stone
- Geosynthetics
    - Geotextile
    - Geomembrane
    - Geosynthetic clay liner
    - Cellular confinement
- Infiltration

Foundations

- Shallow
- Deep

Mechanics	Forces	○ Effective stress ○ Pore water pressure ○ Lateral earth pressure ○ Overburden pressure ○ Preconsolidation pressure

	Phenomena/ problems	○ Permafrost
		○ Frost heaving
		○ Consolidation
		○ Compaction
		○ Earthquake
		    ○ Response spectrum
		    ○ Seismic hazard
		    ○ Shear wave
		○ Landslide analysis
		    ○ Stability analysis
		    ○ Mitigation
		    ○ Classification
		    ○ Sliding criterion
		    ○ Slab stabilisation
		○ Bearing capacity * Stress distribution in soil

Numerical analysis software	○ SEEP2D ○ STABL ○ SVFlux ○ SVSlope ○ UTEXAS ○ Plaxis	

Related fields

- Geology
- Geochemistry
- Petrology
- Earthquake engineering
- Geomorphology
- Soil science
- Hydrology
- Hydrogeology
- Biogeography
- Earth materials
- Archaeology
- Agricultural science
    - Agrology

- v
- t
- e

Construction

Types

- Home construction
- Offshore construction
- Underground construction
    - Tunnel construction

History

- Architecture
- Construction
- Structural engineering
- Timeline of architecture
- Water supply and sanitation

Professions	○ Architect ○ Building engineer ○ Building estimator ○ Building officials ○ Chartered Building Surveyor ○ Civil engineer ○ Civil estimator ○ Clerk of works ○ Project manager ○ Quantity surveyor ○ Site manager ○ Structural engineer ○ Superintendent
Trades workers (List)	○ Banksman ○ Boilermaker ○ Bricklayer ○ Carpenter ○ Concrete finisher ○ Construction foreman ○ Construction worker ○ Electrician ○ Glazier ○ Ironworker ○ Millwright ○ Plasterer ○ Plumber ○ Roofer ○ Steel fixer ○ Welder

Organizations

- American Institute of Constructors (AIC)
- American Society of Civil Engineers (ASCE)
- Asbestos Testing and Consultancy Association (ATAC)
- Associated General Contractors of America (AGC)
- Association of Plumbing and Heating Contractors (APHC)
- Build UK
- Construction History Society
- Chartered Institution of Civil Engineering Surveyors (CICES)
- Chartered Institute of Plumbing and Heating Engineering (CIPHE)
- Civil Engineering Contractors Association (CECA)
- The Concrete Society
- Construction Management Association of America (CMAA)
- Construction Specifications Institute (CSI)
- FIDIC
- Home Builders Federation (HBF)
- Lighting Association
- National Association of Home Builders (NAHB)
- National Association of Women in Construction (NAWIC)
- National Fire Protection Association (NFPA)
- National Kitchen & Bath Association (NKBA)
- National Railroad Construction and Maintenance Association (NRC)
- National Tile Contractors Association (NTCA)
- Railway Tie Association (RTA)
- Royal Institution of Chartered Surveyors (RICS)
- Scottish Building Federation (SBF)
- Society of Construction Arbitrators

By country

- India
- Iran
- Japan
- Romania
- Turkey
- United Kingdom
- United States

Regulation

- Building code
- Construction law
- Site safety
- Zoning

Architecture	◦ Style
	    ◦ List
	◦ Industrial architecture
	    ◦ British
	◦ Indigenous architecture
	◦ Interior architecture
	◦ Landscape architecture
	◦ Vernacular architecture

Engineering	◦ Architectural engineering
	◦ Building services engineering
	◦ Civil engineering
	    ◦ Coastal engineering
	    ◦ Construction engineering
	    ◦ Structural engineering
	◦ Earthquake engineering
	◦ Environmental engineering
	◦ Geotechnical engineering

Methods	◦ List ◦ Earthbag construction ◦ Modern methods of construction ◦ Monocrete construction ◦ Slip forming

Other topics

- Building material
  - List of building materials
  - Millwork
- Construction bidding
- Construction delay
- Construction equipment theft
- Construction loan
- Construction management
- Construction waste
- Demolition
- Design–build
- Design–bid–build
- DfMA
- Heavy equipment
- Interior design
- Lists of buildings and structures
  - List of tallest buildings and structures
- Megaproject
- Megastructure
- Plasterwork
  - Damp
    - Proofing
  - Parge coat
  - Roughcast
    - Harling
- Real estate development
- Stonemasonry
- Sustainability in construction
- Unfinished building
- Urban design
- Urban planning

Image not found or type unknown Outline Image not found or type unknown Category

Authority control databases: National Image not found or type unknown **Edit this at Wikidata**

- Germany
- United States
- Czech Republic
- Israel

About Cook County

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Things To Do in Cook County

Photo

Image not found or type unknown

Sand Ridge Nature Center

4.8 (96)

Photo

Image not found or type unknown

River Trail Nature Center

4.6 (235)

Photo

Image not found or type unknown

Palmisano (Henry) Park

4.7 (1262)

Driving Directions in Cook County

Driving Directions From Palmisano (Henry) Park to

Driving Directions From Lake Katherine Nature Center and Botanic Gardens to

Driving Directions From Navy Pier to

https://www.google.com/maps/dir/Navy+Pier/United+Structural+Systems+of+Illinois%2C+ 87.6050944,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sunknown!2m2!1d-87.6050944!2d41.8918633!1m5!1m1!1sChIJ-wSxDtinD4gRiv4kY3RRh9U!2m2!1d-88.1396465!2d42.0637725!3e0

https://www.google.com/maps/dir/Lake+Katherine+Nature+Center+and+Botanic+Gardens 87.8010774,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sunknown!2m2!1d-87.8010774!2d41.6776048!1m5!1m1!1sChIJ-wSxDtinD4gRiv4kY3RRh9U!2m2!1d-

88.1396465!2d42.0637725!3e2

https://www.google.com/maps/dir/Palmisano+%28Henry%29+Park/United+Structural+Sys
87.6490151,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sunknown!2m2!1d-
87.6490151!2d41.8429903!1m5!1m1!1sChIJ-wSxDtinD4gRiv4kY3RRh9U!2m2!1d-
88.1396465!2d42.0637725!3e1

Reviews for

Image not found or type unknown

Jeffery James

(5)

Very happy with my experience. They were prompt and followed through, and very helpful in fixing the crack in my foundation.

Image not found or type unknown

Sarah McNeily

(5)

USS was excellent. They are honest, straightforward, trustworthy, and conscientious. They thoughtfully removed the flowers and flower bulbs to dig where they needed in the yard, replanted said flowers and spread the extra dirt to fill in an area of the yard. We've had other services from different companies and our yard was really a mess after. They kept the job site meticulously clean. The crew was on time and friendly. I'd recommend them any day! Thanks to Jessie and crew.

Image not found or type unknown

Jim de Leon

(5)

It was a pleasure to work with Rick and his crew. From the beginning, Rick listened to my concerns and what I wished to accomplish. Out of the 6 contractors that quoted the project, Rick seemed the MOST willing to accommodate my wishes. His pricing was definitely more than fair as well. I had 10 push piers installed to stabilize and lift an addition of my house. The project commenced at the date that Rick had disclosed initially and it was completed within the same time period expected (based on Rick's original assessment). The crew was well informed, courteous, and hard working. They were not loud (even while equipment was being utilized) and were well spoken. My neighbors were very impressed on how polite they were when they entered / exited my property (saying hello or good morning each day when they crossed paths). You can tell they care about the customer concerns. They ensured that the property would be put back as clean as possible by placing MANY sheets of plywood down prior to excavating. They compacted the dirt back in the holes extremely well to avoid large stock piles of soils. All the while, the main office was calling me to discuss updates and expectations of completion. They provided waivers of lien, certificates of insurance, properly acquired permits, and JULIE locates. From a construction background, I can tell you that I did not see any flaws in the way they operated and this an extremely professional company. The pictures attached show the push piers added to the foundation (pictures 1, 2 & 3), the amount of excavation (picture 4), and the restoration after dirt was placed back in the pits and compacted (pictures 5, 6 & 7). Please notice that they also sealed two large cracks and steel plated these cracks from expanding further (which you can see under my sliding glass door). I, as well as my wife, are extremely happy that we chose United Structural Systems for our contractor. I would happily tell any of my friends and family to use this contractor should the opportunity arise!

Image not found or type unknown

Chris Abplanalp

(5)

USS did an amazing job on my underpinning on my house, they were also very courteous to the proximity of my property line next to my neighbor. They kept things in order with all the dirt/mud they had to excavate. They were done exactly in the timeframe they indicated, and the contract was very details oriented with drawings of what would be done. Only thing that would have been nice, is they left my concrete a little muddy with boot prints but again, all-in-all a great job

Image not found or type unknown

Dave Kari

(5)

What a fantastic experience! Owner Rick Thomas is a trustworthy professional. Nick and the crew are hard working, knowledgeable and experienced. I interviewed every company in the area, big and small. A homeowner never wants to hear that they have foundation issues. Out of every company, I trusted USS the most, and it paid off in the end. Highly recommend.

Comparing Pier and Beam Home Foundations**View GBP**

Check our other pages :

- **Grasping the Scope of Epoxy Injection Repairs**
- **Considering Carbon Fiber Solutions for Wall Reinforcement**
- **Checking for Stair-Step Cracks Along Walls**
- **Preventing Growth of Small Foundation Cracks**

Frequently Asked Questions

What are the main differences between pier and beam and slab foundations?

Pier and beam foundations consist of piers supporting beams that elevate the home off the ground, allowing for crawl space. Slab foundations are a single, solid concrete slab poured directly onto the ground. Pier and beam foundations are generally more flexible and easier to repair, while slab foundations are more cost-effective and simpler to construct.

What are the common issues with pier and beam foundations that might require repair?

Common issues include sagging or uneven floors due to settling piers, moisture-related problems like mold and rot in the crawl space, and pest infestations. These can lead to structural instability and require foundation repair services.

How does the repair process for pier and beam foundations differ from slab foundations?

Repairing pier and beam foundations often involves adjusting or replacing piers, addressing moisture issues in the crawl space, and reinforcing beams. Slab foundation repairs typically involve lifting and leveling the slab, filling voids underneath, and sometimes installing piers to stabilize the slab. Pier and beam repairs are generally less invasive but may require more frequent maintenance.

What are the cost considerations when choosing between repairing a pier and beam foundation versus replacing it?

Repairing a pier and beam foundation is usually less expensive than a full replacement, with costs depending on the extent of damage and required repairs. Replacement involves demolishing the existing foundation and building a new one, which can be significantly more costly but may be necessary for severe damage or when planning major home renovations.

How can I prevent future issues with my pier and beam foundation?

To prevent future issues, ensure proper drainage around your home to keep the crawl space dry, regularly inspect and maintain the foundation for signs of damage or pest activity, and consider encapsulation of the crawl space to control moisture and improve energy efficiency. Regular professional inspections can also help catch and address problems early.

United Structural Systems of Illinois, Inc

Phone : +18473822882

City : Hoffman Estates

State : IL

Zip : 60169

Address : 2124 Stonington Ave

Google Business Profile

Company Website : **https://www.unitedstructuralsystems.com/**

USEFUL LINKS

Residential Foundation Repair Services