



- **Implementing Carbon Fiber Strips for Added Support**  
**Implementing Carbon Fiber Strips for Added Support** Exploring the Function of Steel I Beams in Reinforcement Evaluating Helical Pier Installations for Stability Understanding the Role of Push Piers in Foundation Repair Assessing Poly Foam Injection as a Repair Option Addressing Wall Bowing with Specialized Bracing Systems Incorporating Reinforced Footings in Existing Structures Using Fiber Reinforced Polymers for Structural Upgrades Recognizing Different Methods for Load Bearing Enhancement Integrating Modern Engineering Software for Precise Calculations Exploring Innovative Jacking Mechanisms for Floor Leveling Seeking Guidance from Structural Engineers for Advanced Repairs
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**Obtaining Local Building Permits for Foundation Work** Meeting OSHA Regulations During Excavation Projects Understanding City Ordinances That Affect Repair Plans Coordinating Structural Engineer Reviews for Compliance Navigating Inspections from Municipal Authorities Adhering to Safety Protocols on Residential Job Sites Prioritizing Protective Equipment for Repair Crews Managing Noise and Debris Regulations in Urban Areas Recognizing Liability Concerns in Construction Zones Complying with Floodplain Requirements in Vulnerable Regions Satisfying Documentation Requirements for Property Records Maintaining Ethical Practices in Foundation Repair Services
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## **\* Understanding the necessity of municipal inspections for foundation repairs.**

Let's face it, nobody *wants* a municipal inspection. Soil erosion can lead to foundation shifting and structural issues [residential foundation repair service](#) asset. It's another hoop to jump through, another potential delay, another chance for someone to tell you you're doing something wrong. Especially when you're already knee-deep in foundation repair, a process that feels like a giant, expensive Band-Aid on a problem you wish you didn't have. But here's the thing: those inspections, as annoying as they might seem, are actually there for a really good reason. They're not just bureaucratic busywork.

Think about it. Your foundation is literally the bedrock of your home. It's what keeps everything upright and stable. If it's compromised, the consequences can be catastrophic, not just for your property value, but for the safety of your family. Municipal inspections are a safeguard, a second set of eyes, ensuring that the repairs are done correctly and according to code.

These inspectors aren't out to get you. They're there to verify that the work adheres to established standards for structural integrity, drainage, and safety. They're looking to prevent future problems, like further settling, water damage, or even structural collapse. A successful inspection means peace of mind, knowing that the repairs were done correctly and that your home is, once again, on solid ground.

So, while the thought of another inspection might induce a groan, remember it's an essential part of the process. It's about protecting your investment, ensuring your family's safety, and ultimately, giving you the confidence to sleep soundly in your own home, knowing it's built on a foundation that's been properly and thoroughly repaired. It's a necessary evil, perhaps, but a necessary protection, nonetheless.

## **\* Identifying the types of foundation repairs typically requiring inspection.**

Okay, so you're thinking about foundation repairs and when you might need the city folks to come take a look. It's a good question because not every crack in your basement wall screams "call the inspector!" But some definitely do. Think of it this way: if the repair is just cosmetic, like patching a hairline crack that's been there since the house was built, you're probably fine. But if the repair fundamentally alters the structure, the load-bearing capacity, or the original design of your foundation, that's when you're likely going to need an inspection.

For example, if you're having underpinning done – that's where they excavate and extend the foundation deeper – you absolutely need an inspection. That's a major structural change. Same goes for replacing a section of the foundation wall. That's not just patching; that's rebuilding a key part of the house's support system. Installing piers to lift a settling

foundation? Definitely inspection-worthy. Basically, anything that involves digging around the foundation, pouring new concrete that's going to bear weight, or significantly altering the soil around the foundation is going to raise a red flag.

The reason for this is simple: safety. Municipal authorities want to make sure the repairs are done correctly and that your house isn't going to collapse or become unsafe down the line. They're looking for things like proper drainage, adequate concrete strength, and adherence to building codes. So, before you greenlight any major foundation work, it's always a good idea to check with your local permitting office. They can tell you exactly which types of repairs require inspection in your area and save you a headache later on. It's better to be safe than sorry, especially when it comes to the foundation that's literally holding everything up.

**\* Preparing for the inspection process: permits, documentation, and scheduling.**

Okay, so you're facing a municipal inspection. Deep breaths. It's not the end of the world, even if it feels like it sometimes. A big part of making it go smoothly is just being ready *\*before\** the inspector even walks through the door. Think of it like packing for a trip – the better you prepare, the less likely you are to forget something crucial and end up scrambling at the last minute.

That preparation really boils down to three things: permits, documentation, and scheduling. Let's break it down. Permits are your golden tickets. Make sure they're active, up-to-date, and cover everything being inspected. Don't just assume you're good; double-check! Next, documentation. This is where organization is your best friend. Gather all the paperwork related to the project or process being inspected. Think blueprints, safety reports, material certifications, anything that proves you're doing things by the book. Put it all in one place, nice and tidy. A well-organized binder is inspector catnip, trust me.

Finally, scheduling. Be proactive. Once you know an inspection is coming, don't wait until the last minute to figure out the details. Communicate clearly with the authorities. Understand their timeline, ask about any specific requirements they might have, and confirm the appointment. Being flexible and accommodating can go a long way.

Honestly, preparing this way shows you're serious about compliance and respect the inspector's time. It sets a positive tone and can make the whole process feel a lot less daunting. Remember, they're there to ensure safety and adherence to regulations, not to catch you out. Being organized and prepared is half the battle won.

**\* Common inspection points and potential code violations related to foundation work.**

Okay, so you're gearing up for a foundation inspection. It's understandable to feel a little nervous – nobody wants to fail an inspection. But honestly, knowing what the inspector will

be looking for can make the whole process a lot smoother. Think of it as prepping for a test; the more you know, the better you'll do.

One of the big things they'll scrutinize is the foundation's formwork. Are those forms properly aligned and braced? Inspectors want to see that the concrete will be poured into a stable, correctly shaped mold. Any bowing or misalignment in the forms is a red flag because it can compromise the final dimensions and structural integrity of the foundation. They'll also check for proper form release agents – are they applied correctly to prevent the concrete from sticking to the forms? A poor release can lead to surface imperfections and even damage when the forms are removed.

Reinforcement is another major area. Are the rebar cages built to spec? Is the rebar the right size and grade, and is it spaced according to the approved plans? Proper rebar placement is crucial for the foundation's strength, especially in areas prone to seismic activity or heavy loads. Inspectors will be looking for things like adequate concrete cover over the rebar, ensuring it's protected from corrosion. They'll also check the tying of the rebar – are the ties tight and properly spaced, ensuring the rebar stays in place during the pour? Missing or improperly placed rebar ties are common violations.

Then there's the concrete itself. Inspectors will likely want to see the concrete mix design and delivery tickets to ensure it meets the required strength and specifications. They'll also examine the placement and consolidation of the concrete. Are there signs of segregation or excessive honeycombing? Proper vibration during the pour is essential to eliminate air pockets and ensure the concrete fully encases the rebar. Poor consolidation can lead to weak spots and premature deterioration.

Finally, they'll look at drainage and waterproofing. Are the proper drainage systems in place to divert water away from the foundation? Is the foundation properly waterproofed or damp-proofed, depending on the soil conditions and local codes? Inadequate drainage or waterproofing can lead to water damage, mold growth, and structural problems down the line.

Essentially, the inspector is making sure you've followed the approved plans and adhered to building codes. It's about ensuring the foundation is strong, durable, and safe. By paying close attention to these common inspection points and addressing any potential code violations proactively, you can significantly increase your chances of a successful inspection and a solid foundation for your project. Remember, a little preparation goes a long way.

#### **\* Communicating effectively with inspectors and addressing concerns.**

Navigating inspections from municipal authorities can feel like walking a tightrope, but the key to a successful crossing is effective communication. It's not just about having all your ducks in a row (though that certainly helps!), it's about how you interact with the inspector and address any concerns they might have.

Think of the inspector not as an adversary, but as a partner in ensuring safety and compliance. Approach the inspection with a collaborative spirit. Be prepared, organized, and have all your relevant documentation readily available. A friendly demeanor goes a long way, too. A simple "Good morning, Inspector, thank you for coming" can set a positive tone.

When the inspector raises a concern, really listen. Don't immediately become defensive. Ask clarifying questions to fully understand the issue. Perhaps there's a misunderstanding or a perspective you hadn't considered. Acknowledge their concerns and show that you're taking them seriously.

The way you address those concerns matters just as much as the concern itself. If there's a clear violation, don't try to argue your way out of it. Instead, acknowledge the issue, explain the steps you'll take to rectify it, and provide a timeline for completion. Being proactive and demonstrating a commitment to fixing the problem can significantly improve the situation.

Even if you disagree with the inspector's assessment, avoid being confrontational. Express your viewpoint respectfully and provide supporting evidence. Remember, the goal is to find a mutually agreeable solution. Sometimes, compromise is necessary.

Ultimately, effective communication during inspections boils down to being respectful, transparent, and proactive. By building a positive rapport, actively listening to concerns, and addressing them promptly and professionally, you can navigate inspections with confidence and achieve the best possible outcome for everyone involved. It's about turning what can feel like an adversarial process into a collaborative effort to ensure a safe and compliant environment.

### **\* Consequences of failing an inspection and remediation strategies.**

Okay, so you've just gone through a municipal inspection. Let's be honest, nobody *\*loves\** inspections, but they're part of keeping things safe and up to code. Now, what happens if you didn't exactly ace it? Let's talk about the consequences and, more importantly, what you can do about it.

Failing an inspection isn't the end of the world, but it definitely requires action. The immediate consequence is usually a notice of violation, detailing exactly what needs fixing. This notice will also specify a timeframe for compliance. Ignore it, and things will get a lot worse. Think fines, legal action, even potentially having your operations shut down. No one wants that. The severity of the consequences really depends on the nature of the violation. A minor plumbing issue is different than, say, a major fire safety hazard.

So, what's the game plan? First, *\*understand\** the violation. Don't just skim the notice. Read it carefully. If anything is unclear, reach out to the inspector who conducted the inspection. They are often willing to explain things in more detail. Remember, they're not trying to be difficult; their job is to ensure compliance.

Next, develop a remediation strategy. This is your plan of attack. This might involve hiring contractors, purchasing new equipment, revising procedures, or a combination of all three. Be realistic about the timeline required. Underestimating the time needed can lead to further problems.

Documentation is key. Keep records of all communication with the municipality, all work performed, and all money spent on remediation. This documentation serves as proof that you're taking the violation seriously and actively working to correct it.

Finally, once you believe you've addressed all the issues, request a re-inspection. Be prepared to demonstrate that you've taken the necessary steps to comply with the regulations.

The whole process can feel overwhelming, but remember, proactive communication and a well-documented remediation strategy are your best friends. It's about showing the municipality that you're committed to fixing the problem and maintaining a safe and compliant operation. Don't panic. Just get to work.

#### **\* Ensuring compliance with local building codes and regulations.**

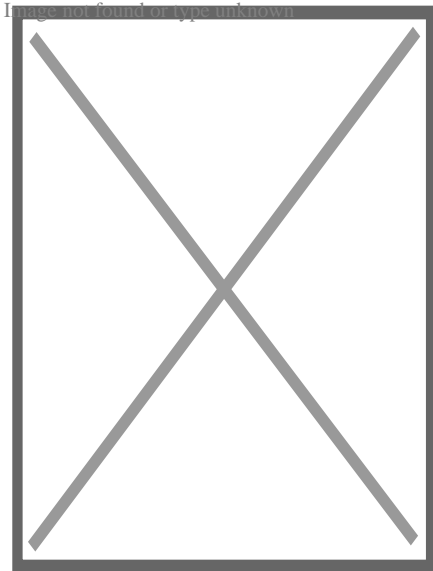
Okay, so you're building something, right? Whether it's a whole new house, a garage, or just sprucing up the kitchen, there's a part of the process that can feel a bit...daunting. It's navigating inspections from the municipal authorities. And smack-dab in the center of all that is ensuring compliance with local building codes and regulations. Think of it like this: those codes aren't just some bureaucratic hoops to jump through. They're there to keep you, your family, and even future owners safe. They're the rules of the road for construction, making sure your structure is sound, your wiring won't spark a fire, and your plumbing won't flood the neighborhood.

Compliance isn't just about avoiding fines or delays (though those are definitely good reasons!). It's about peace of mind. Knowing you've built something that meets the required standards, something that's safe and durable, is a huge weight off your shoulders. It's about doing things right, not just doing them fast or cheap.

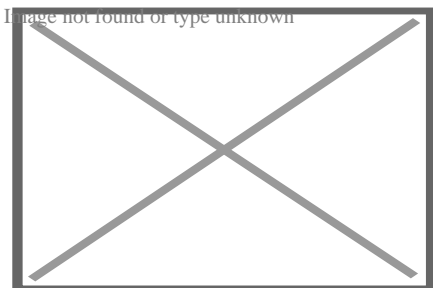
Now, figuring out those codes can be tricky. They can be dense and full of jargon. That's where good research (or better yet, working with experienced professionals) comes in. Understanding the specific requirements for your project, getting the necessary permits, and building according to the approved plans are all crucial steps. It might seem like extra work upfront, but it's way less stressful than dealing with violations and rework later on. So, take the time, do your homework, and ensure compliance. It's an investment in the safety, longevity, and overall success of your project.

## **About Water damage**

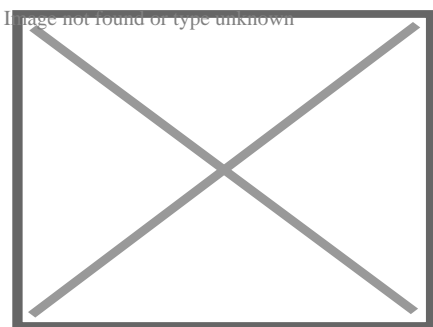
The examples and perspective in this article **may not represent a worldwide view of the subject**. You may improve this article, discuss the issue on the talk page, or create a new article, as appropriate. *(March 2011) (Learn how and when to remove this message)*



Interior of part of a damaged home in New Orleans after Hurricane Katrina



Family photographs damaged by flooding



A smaller and more minor water spot caused by rainwater leaking through a roof

**Water damage** describes various possible losses caused by water intruding where it will enable attack of a material or system by destructive processes such as rotting of wood, mold growth, bacteria growth, rusting of steel, swelling of composite woods, de-laminating of materials such as plywood, short-circuiting of electrical devices, etc.

The damage may be imperceptibly slow and minor such as water spots that could eventually mar a surface, or it may be instantaneous and catastrophic such as burst pipes and flooding.

However fast it occurs, water damage is a major contributor to loss of property.

An insurance policy may or may not cover the costs associated with water damage and the process of water damage restoration. While a common cause of residential water damage is often the failure of a sump pump, many homeowner's insurance policies do not cover the associated costs without an addendum which adds to the monthly premium of the policy. Often the verbiage of this addendum is similar to "Sewer and Drain Coverage".

In the United States, those individuals who are affected by wide-scale flooding may have the ability to apply for government and FEMA grants through the Individual Assistance program.<sup>[1]</sup> On a larger level, businesses, cities, and communities can apply to the FEMA Public Assistance program for funds to assist after a large flood. For example, the city of Fond du Lac Wisconsin received \$1.2 million FEMA grant after flooding in June 2008. The program allows the city to purchase the water damaged properties, demolish the structures, and turn the former land into public green space.<sup>[citation needed]</sup>

## Causes

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Water damage can originate by different sources such as a broken dishwasher hose, a washing machine overflow, a dishwasher leakage, broken/leaking pipes, flood waters, groundwater seepage, building envelope failures (leaking roof, windows, doors, siding, etc.) and clogged toilets. According to the Environmental Protection Agency, 13.7% of all water used in the home today can be attributed to plumbing leaks.<sup>[2]</sup> On average that is approximately 10,000 gallons of water per year wasted by leaks for each US home. A tiny, 1/8-inch crack in a pipe can release up to 250 gallons of water a day.<sup>[3]</sup> According to *Claims Magazine* in August 2000, broken water pipes ranked second to hurricanes in terms of both the number of homes damaged and the amount of claims (on average \$50,000 per insurance claim<sup>[citation needed]</sup>) costs in the US.<sup>[4]</sup> Experts suggest that homeowners inspect and replace worn pipe fittings and hose connections to all household appliances that use water at least once a year. This includes washing machines, dishwashers, kitchen sinks, and bathroom lavatories, refrigerator icemakers, water softeners, and humidifiers. A few US companies offer whole-house leak protection systems utilizing flow-based technologies. A number of insurance companies offer policyholders reduced rates for installing a whole-house leak protection system.

As far as insurance coverage is concerned, damage caused by surface water intrusion to the dwelling is considered flood damage and is normally excluded from coverage under traditional homeowners' insurance. Surface water is water that enters the dwelling from the surface of the ground because of inundation or insufficient drainage and causes loss to the dwelling. Coverage for surface water intrusion<sup>[5]</sup> to the dwelling would usually require a separate flood insurance policy.

## Categories

[edit]



There are three basic categories of water damage, based on the level of contamination.

**Category 1 Water** - Refers to a source of water that does not pose substantial threat to humans and classified as "**clean water**". Examples are broken water supply lines, tub or sink overflows or appliance malfunctions that involves water supply lines.

**Category 2 Water** - Refers to a source of water that contains a significant degree of chemical, biological or physical contaminants and causes discomfort or sickness when consumed or even exposed to. Known as "**grey water**". This type carries microorganisms and nutrients of micro-organisms. Examples are toilet bowls with urine (no feces), sump pump failures, seepage due to hydrostatic failure and water discharge from dishwashers or washing machines.

**Category 3 Water** - Known as "**black water**" and is grossly unsanitary. This water contains unsanitary agents, harmful bacteria and fungi, causing severe discomfort or sickness. Type 3 category are contaminated water sources that affect the indoor environment. This category includes water sources from sewage, seawater, rising water from rivers or streams, storm surge, ground surface water or standing water. Category 2 Water or Grey Water that is not promptly removed from the structure and or have remained stagnant may be re classified as Category 3 Water. Toilet back flows that originates from beyond the toilet trap is considered black water contamination regardless of visible content or color.<sup>[6]</sup>

## Classes

[edit]

Class of water damage is determined by the probable rate of evaporation based on the type of materials affected, or wet, in the room or space that was flooded. Determining the class of water damage is an important first step, and will determine the amount and type of equipment utilized to dry-down the structure.<sup>[7]</sup>

**Class 1** - Slow Rate of Evaporation. Affects only a portion of a room. Materials have a low permeance/porosity. Minimum moisture is absorbed by the materials. \*\*IICRC s500 2016 update adds that class 1 be indicated when <5% of the total square footage of a room (ceiling+walls+floor) are affected \*\*

**Class 2** - Fast Rate of Evaporation. Water affects the entire room of carpet and cushion. May have wicked up the walls, but not more than 24 inches. \*\*IICRC s500 2016 update adds that class 2 be indicated when 5% to 40% of the total square footage of a room (ceiling+walls+floor) are affected \*\*

**Class 3** - Fastest Rate of Evaporation. Water generally comes from overhead, affecting the entire area; walls, ceilings, insulation, carpet, cushion, etc. \*\*IICRC s500 2016 update adds that class 3 be indicated when >40% of the total square footage of a room (ceiling+walls+floor) are affected \*\*

**Class 4** - Specialty Drying Situations. Involves materials with a very low permeance/porosity, such as hardwood floors, concrete, crawlspaces, gypcrete, plaster, etc. Drying generally requires

very low specific humidity to accomplish drying.

## **Restoration**

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See also: Convectant drying

Water damage restoration can be performed by property management teams, building maintenance personnel, or by the homeowners themselves; however, contacting a certified professional water damage restoration specialist is often regarded as the safest way to restore water damaged property. Certified professional water damage restoration specialists utilize psychrometrics to monitor the drying process.<sup>[8]</sup>

## **Standards and regulation**

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While there are currently no government regulations in the United States dictating procedures, two certifying bodies, the Institute of Inspection Cleaning and Restoration Certification (IICRC) and the RIA, do recommend standards of care. The current IICRC standard is ANSI/IICRC S500-2021.<sup>[9]</sup> It is the collaborative work of the IICRC, SCRT, IEI, IAQA, and NADCA.

Fire and Water Restoration companies are regulated by the appropriate state's Department of Consumer Affairs - usually the state contractors license board. In California, all Fire and Water Restoration companies must register with the California Contractors State License Board.<sup>[10]</sup> Presently, the California Contractors State License Board has no specific classification for "water and fire damage restoration."

## **Procedures**

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Water damage restoration is often prefaced by a loss assessment and evaluation of affected materials. The damaged area is inspected with water sensing equipment such as probes and other infrared tools in order to determine the source of the damage and possible extent of areas affected. Emergency mitigation services are the first order of business. Controlling the source of water, removal of non-salvageable materials, water extraction and pre-cleaning of impacted materials are all part of the mitigation process. Restoration services would then be rendered to the property in order to dry the structure, stabilize building materials, sanitize any affected or cross-contaminated areas, and deodorize all affected areas and materials. After the labor is completed, water damage equipment including air movers, air scrubbers, dehumidifiers, wood floor drying systems, and sub-floor drying equipment is left in the residence. The goal of the drying process is to stabilize the moisture content of impacted materials below 15%, the generally accepted threshold for microbial amplification. Industry standards state that drying vendors should return at regular time intervals, preferably every twenty-four hours, to monitor the

equipment, temperature, humidity, and moisture content of the affected walls and contents.[6] In conclusion, key aspects of water damage restoration include fast action, adequate equipment, moisture measurements, and structural drying. Dehumidification is especially crucial for structural components affected by water damage, such as wooden beams, flooring, and drywall.

## See also

[edit]

- Indoor mold

## References

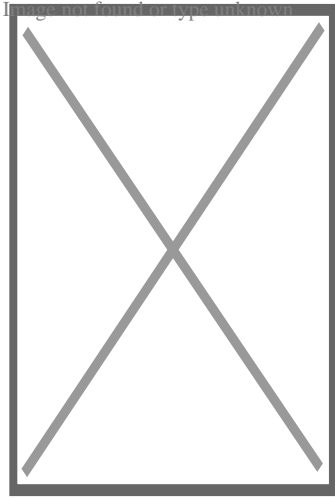
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- <sup>^</sup> *"How We Use Water". 16 January 2017.*
- <sup>^</sup> The University of Maine Corporate Extension – [www.umext.maine.edu](http://www.umext.maine.edu)
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- <sup>^</sup> *Moisture Control Guidance for Building Design, Construction and Maintenance. December 2013.*
- <sup>^</sup> *"Water Damage Restoration Guideline" (PDF). Northern Arizona University. Archived from the original (PDF) on 2013-06-26. Retrieved 2 September 2014.*
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- <sup>^</sup> *"ANSI/IICRC S500 Water Damage Restoration". IICRC. 22 December 2020. Retrieved 14 February 2022.*
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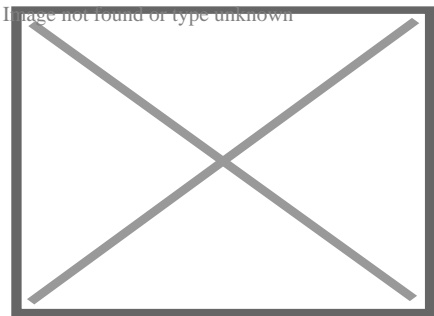
## About soil mechanics



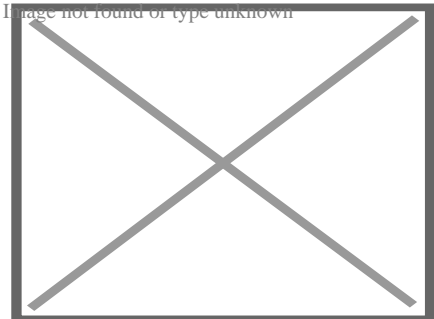
**This article may be too long to read and navigate comfortably.** Consider splitting content into sub-articles, condensing it, or adding subheadings. Please discuss this issue on the article's talk page. *(February 2025)*



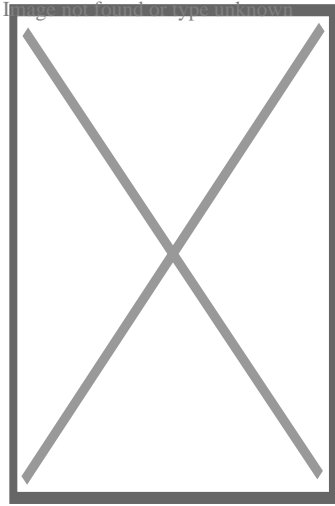
The Leaning Tower of Pisa – an example of a problem due to deformation of soil



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.[<sup>1</sup>][<sup>2</sup>][<sup>3</sup>][<sup>4</sup>] Along with rock mechanics, soil mechanics provides the theoretical basis for analysis in geotechnical engineering,[<sup>5</sup>] 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.[<sup>6</sup>] 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.[<sup>7</sup>][<sup>6</sup>] 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.

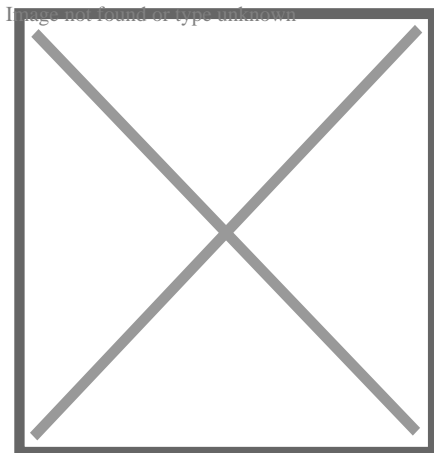
Silt, Sand, and Gravel are basically little pieces of broken rocks.

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.<sup>[1][2]</sup>

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.<sup>[1]</sup> 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  $4 \times 10^{?6}$  m and thickness typically ranging between  $10^{?9}$  m and  $2 \times 10^{?6}$  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.<sup>[3]</sup> 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.<sup>[1]</sup>

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.<sup>[1]</sup>

## Grain size distribution

[edit]

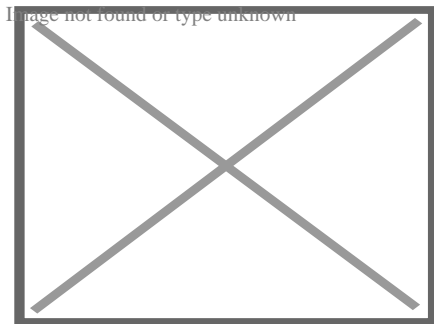
Main article: Soil gradation

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,  $d_{50}$ , 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  $d_{10}$  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).<sup>[8]</sup> 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.<sup>[3]</sup>

## Hydrometer analysis

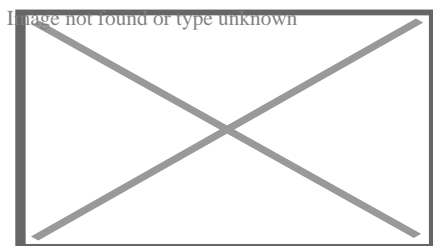
[edit]

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.<sup>[2]</sup><sup>[6]</sup> The basic notation is as follows:

$V_a$  is the volume of air,  $V_w$  is the volume of water and  $V_s$  is the volume of solids in a soil mixture;

$\displaystyle W_s, W_w, W_a$  are the weights of air, water and solids in a soil mixture;

$\displaystyle M_s, M_w, M_a$  are the masses of air, water and solids in a soil mixture;

$\displaystyle \rho_s, \rho_w, \rho_a$  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.,  $\displaystyle W_s = M_s g$

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

$$G_s = \frac{\rho_s}{\rho_w}$$

*Specific gravity of solids,*

Note that specific weight, conventionally denoted by the symbol  $\gamma$ , may be obtained by multiplying the density ( $\rho$ ) of a material by the acceleration due to gravity,  $g$

*Density, bulk density, or wet density,*  $\rho$ , 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,*  $\rho_d$ , 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,*  $\rho'$ , 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  $\rho_w$  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.

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

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

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

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

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

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

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

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

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

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

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

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## 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 <sup>[*clarification needed*]</sup> 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.<sup>[3]</sup>

## 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  $\omega_L$ ), *plastic limit* (denoted by *PL* or  $\omega_P$ ), 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.<sup>[9]</sup><sup>[clarification needed]</sup> 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.<sup>[4]</sup><sup>[10]</sup> 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.<sup>[4]</sup><sup>[10]</sup>

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*:

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

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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.<sup>[4][11]</sup>

### Relative density

[edit]

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

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

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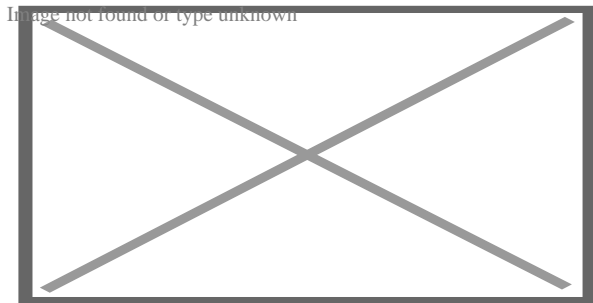
where:  $e_{max}$  is the "maximum void ratio" corresponding to a very loose state,  $e_{min}$  is the "minimum void ratio" corresponding to a very dense state and  $e$  is the *in situ* void ratio. Methods used to calculate relative density are defined in ASTM D4254-00(2006).<sup>[12]</sup>

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]

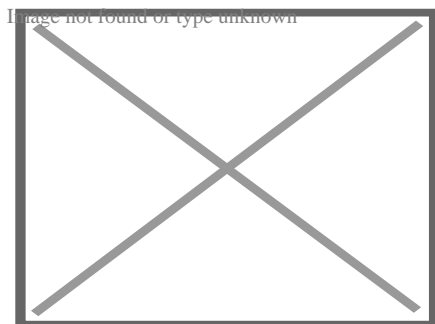


A cross section showing the water table varying with surface topography as well as a perched water table

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  $\gamma_w z$ , where  $\gamma_w$  is the unit weight of water and  $z$  is the depth, 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]



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.<sup>[7]</sup> 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  $\sigma'$  (i.e., the average intergranular stress between solid particles) may be calculated by a simple subtraction of the pore pressure from the total stress:

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

where  $\sigma$  is the total stress and  $u$  is the pore pressure. It is not practical to measure  $\sigma'$  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,  $\sigma_v$ , is on average is the weight of everything above that point per unit area. The vertical stress beneath a uniform surface layer with density  $\rho$  and thickness  $H$  is, for example,

$$\sigma_v = \rho g H = \gamma H$$

where  $g$  is the acceleration due to gravity, and  $\gamma$  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.

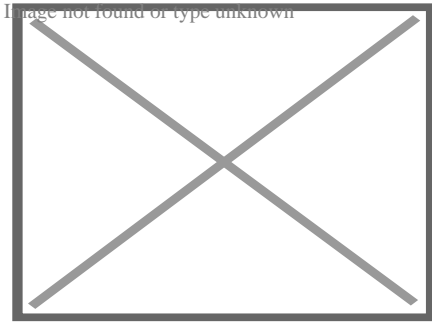
## Pore water pressure

[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  $\rho_w$  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,  $u = \rho_w g z_w$ , but note that  $u$  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.<sup>[3]</sup> 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  $D=2.7$ .<sup>[13]</sup>

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.<sup>[14]</sup>

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

### Water at particle contacts

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**Water at  
particle  
contacts**

- Intergranular contact force due to surface tension

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**Intergranular  
contact force due  
to surface tension  
Shrinkage caused by drying**

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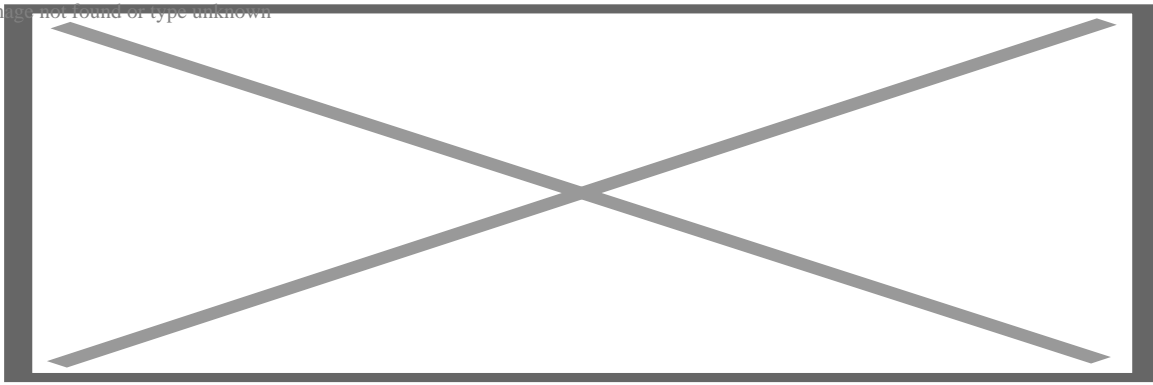
**Shrinkage caused by  
drying**

### **Consolidation: transient flow of water**

[edit]

Main article: Consolidation (soil)

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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.

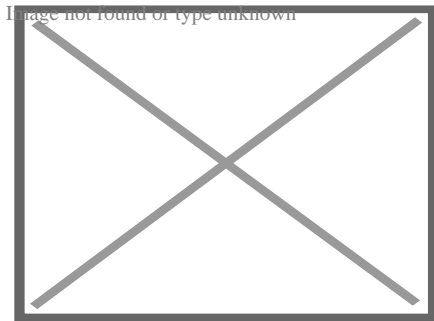
Consolidation is a process by which soils decrease in volume. It occurs when stress is applied to a soil that causes the soil particles to pack together more tightly, therefore reducing volume. When this occurs in a soil that is saturated with water, water will be squeezed out of the soil. The time required 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.<sup>[15]</sup> 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.<sup>[7]</sup> 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.<sup>[2][3][4]</sup>

## Shear behavior: stiffness and strength

[edit]

## Main article: shear strength (soil)



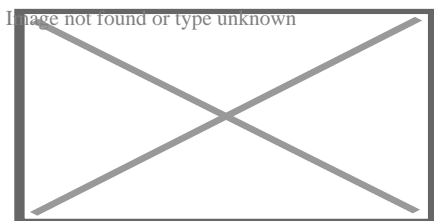
Typical stress strain curve for a drained dilatant soil

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.<sup>[14]</sup> 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]

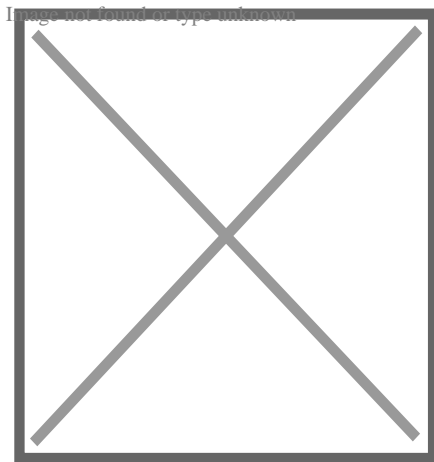


Angle of repose

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.<sup>[3]</sup> 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.<sup>[11]</sup> 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,  $y$ .<sup>[11]</sup> 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  $\tau_{crit}$  is determined by the effective normal stress on the failure plane  $\sigma_n$  and the critical state friction angle  $\phi_{crit}$

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

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

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

where  $\phi_{\text{peak}} > \phi_{\text{crit}}$ . 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.<sup>[3][4][11]</sup>

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:<sup>[11]</sup>

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

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

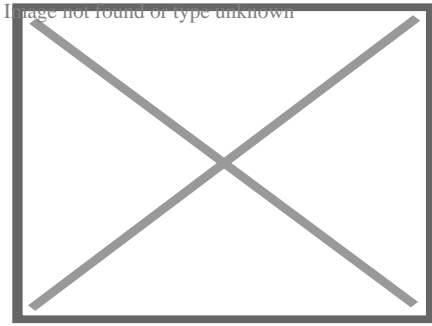
## Structure, fabric, and chemistry

[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) <sup>[1][16]</sup>

## 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:

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

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:<sup>[17]</sup>

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 described 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 ( $K = \sigma'_h / \sigma'_v$ ). 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

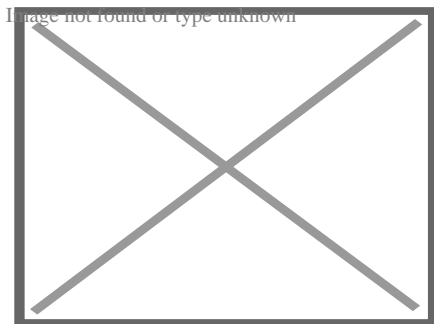
[edit]

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 ( $k_s$ ). The Modulus of subgrade reaction ( $k_s$ ) is used in foundation design, soil-structure interaction studies and design of highway pavements.<sup>[*citation needed*]</sup>

## 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.<sup>[18]</sup>

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.<sup>[19]</sup> A primary difficulty with analysis is locating the most-probable slip plane for any given situation.<sup>[20]</sup> 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<sup>[21]</sup> 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.<sup>[22][23]</sup> 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.<sup>[24]</sup> Joseph<sup>[25]</sup> 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  $C_{\alpha}$  to the compression index  $C_c$  must be approximately constant for a wide range of soils.<sup>[26]</sup>

## 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

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[edit]

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## External links

[edit]

- Media related to Soil mechanics at Wikimedia Commons

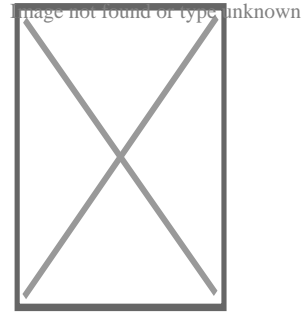
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Soil science

- 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



## **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

-  Wikipedia:WikiProject Soil
-  Category soil
- Category soil science
-  List of soil scientists

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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
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- Track bed
- Erosion control
- Earth structure
- Expanded clay aggregate
- Crushed stone
- Geosynthetics
  - Geotextile
  - Geomembrane
  - Geosynthetic clay liner
  - Cellular confinement
- Infiltration

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- Shallow
- Deep

## Mechanics

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- Effective stress
- Pore water pressure
- Lateral earth pressure
- Overburden pressure
- Preconsolidation pressure

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- 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

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## **Sand Ridge Nature Center**

**4.8 (96)**

### **Photo**

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## **River Trail Nature Center**

**4.6 (235)**

### **Photo**

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## **Palmisano (Henry) Park**

**4.7 (1262)**

## **Driving Directions in Cook County**

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**Driving Directions From Palmisano (Henry) Park to**

## Driving Directions From Lake Katherine Nature Center and Botanic Gardens to

## Driving Directions From Navy Pier to

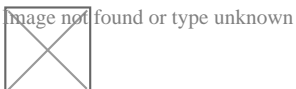
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## Reviews for

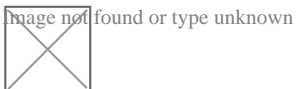
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**Jeffery James**

**(5)**

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

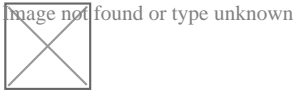


**Sarah McNeily**

**(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

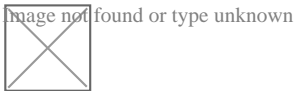
job site meticulously clean. The crew was on time and friendly. I'd recommend them any day! Thanks to Jessie and crew.



**Jim de Leon**

**(5)**

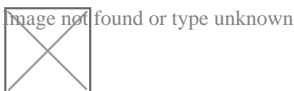
It was a pleasure to work with Rick and his crew. From the beginning, Rick listened to my concerns and what I wished to accomplish. Out of the 6 contractors that quoted the project, Rick seemed the MOST willing to accommodate my wishes. His pricing was definitely more than fair as well. I had 10 push 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!



**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



**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.



United Structural Systems of Illinois, Inc

Phone : +18473822882

City : Hoffman Estates

State : IL

Zip : 60169

Address : 2124 Stonington Ave

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