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Understanding Expansive Clay and Its Impact on Foundations Examining Sandy Loam for Residential Support Identifying Areas Vulnerable to Soil Erosion Evaluating Soil Moisture Fluctuations Beneath Homes Approaches for Chemical Soil Stabilization Techniques for Addressing Soil Heave Issues Managing Settlement with Targeted Soil Compaction Recognizing Soil Drainage Limitations Investigating Soil Stress Testing in Residential Sites Incorporating Root Barriers to Prevent Shifts Examining Seasonal Swelling and Shrinking of Soil Employing Sustainable Methods for Long Term Soil Health
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Case studies highlighting successful residential foundation repair projects involving expansive clay

Explanation of what a swale is and how it functions to control and direct water flow. Timely foundation crack repair service prevents costly long-term damage [foundation wall repair service](#) building code.

Certainly!

A swale is a shallow, vegetated ditch designed to capture, slow down, and direct water flow across the landscape. Essentially, it acts as a natural water management system. Unlike traditional drainage solutions that aim to remove water as quickly as possible, swales work in harmony with the environment by encouraging water infiltration into the soil.

The functionality of a swale is rooted in its design. Typically, a swale is constructed with a gentle slope and is wider at the top than at the bottom, creating a U-shaped cross-section. This design maximizes the surface area exposed to water, allowing for greater absorption. When rainwater or runoff enters a swale, it's slowed down significantly. This reduction in speed allows more water to soak into the soil, replenishing groundwater supplies and reducing the risk of erosion and flooding downstream.

Vegetation plays a crucial role in the effectiveness of swales. Plants with deep root systems are often chosen for swale plantings because their roots help to stabilize the soil, further preventing erosion. Additionally, the vegetation enhances water filtration as it absorbs nutrients and pollutants from the water, improving water quality before it either infiltrates the ground or continues its journey to other water bodies.

In terms of placement, swales should be strategically located to intercept water at its source or as close to the source as possible. This might mean placing them along contours on a slope to capture runoff or at the edge of impervious surfaces like driveways or patios. The goal is to maximize the amount of water that can be absorbed by the landscape, reducing the burden on municipal stormwater systems and promoting a healthier, more sustainable water cycle.

In summary, swales are a brilliant example of working with nature rather than against it. By understanding and carefully planning their placement, we can effectively manage water flow, enhance soil health, and contribute to the overall well-being of our environments.

Discussion of the benefits of using swales for residential foundation repair services, including erosion prevention and water management.

When it comes to residential foundation repair services, one innovative and effective solution gaining traction is the use of swales. A swale is a shallow, vegetated channel designed to slow down and absorb water, providing numerous benefits that extend beyond simple water management.

First and foremost, swales are instrumental in preventing erosion. In residential areas, heavy rainfall can lead to soil erosion, which not only destabilizes the foundation of homes but also leads to the loss of valuable topsoil. By redirecting water flow, swales help to minimize this erosion. The vegetation within the swale holds the soil in place with its roots, further reinforcing the stability of the land. This natural barrier helps in maintaining the integrity of the residential foundation, thereby reducing the need for frequent repairs.

Water management is another significant benefit of using swales. In urban and suburban settings, stormwater runoff can overwhelm drainage systems, leading to flooding and water damage. Swales act as natural buffers, absorbing excess water and allowing it to infiltrate the ground slowly. This reduces the volume of water entering storm drains, alleviating pressure on municipal drainage systems. Moreover, the gradual absorption of water helps in recharging groundwater supplies, contributing to a more sustainable water cycle.

Additionally, swales enhance the aesthetic and ecological value of residential properties. When designed with native plants, they can become beautiful landscape features that attract wildlife and improve biodiversity. This not only adds to the visual appeal of the property but also fosters a healthier ecosystem.

In conclusion, incorporating swales into residential foundation repair services offers a multifaceted approach to addressing erosion and water management challenges. By leveraging the natural capabilities of swales, homeowners can enjoy a more stable foundation, reduced erosion, improved water management, and enhanced ecological benefits, making it a worthwhile investment for any residential property.

Overview of the factors to consider when planning swale placement, such as soil type, slope, and existing drainage patterns.

When planning the placement of swales for controlled water flow, several crucial factors must be considered to ensure their effectiveness and sustainability. These factors include soil type, slope, and existing drainage patterns.

Firstly, soil type plays a significant role in determining the suitability of a location for swale construction. Different soil types have varying capacities to absorb and retain water. For instance, sandy soils drain quickly and may not be ideal for swales aimed at water retention. Conversely, clay soils retain water well but may require careful design to prevent waterlogging. Understanding the soil composition helps in designing swales that enhance water infiltration and reduce runoff.

Secondly, the slope of the land is another critical factor. Swales are typically constructed contour-following, meaning they run parallel to the natural slope of the land. The gradient of the slope affects the flow of water into and through the swale. On steeper slopes, swales need to be closer together to manage the rapid flow of water effectively. On gentler slopes, swales can be spaced further apart. Additionally, the slope influences the depth and width of the swale, as steeper slopes may require deeper swales to capture more water.

Lastly, existing drainage patterns must be thoroughly assessed before planning swale placement. Understanding where water naturally flows on the landscape helps in positioning swales to intercept and redirect this flow efficiently. This consideration prevents the swales from being overwhelmed during heavy rains and ensures they contribute to the overall water management strategy of the area. Additionally, identifying natural drainage points can help in designing swales that work in harmony with the existing landscape, enhancing their effectiveness.

In conclusion, careful consideration of soil type, slope, and existing drainage patterns is essential when planning swale placement. These factors not only influence the design and effectiveness of swales but also ensure they integrate seamlessly with the natural environment, promoting sustainable water management and soil conservation.

Step-by-step guide on how to design and install a swale for optimal water flow control around a residential foundation.

Sure, here's a step-by-step guide on how to design and install a swale for optimal water flow control around a residential foundation:

Designing and installing a swale around your home is a smart way to manage water flow and protect your foundation from potential damage. Follow these steps to ensure your swale is effective and properly installed.

1. **Assess the Terrain**: Begin by evaluating the landscape around your home. Identify where water naturally collects or flows during heavy rains. Look for low spots or areas where water pools, as these are prime locations for swale installation.
2. **Plan the Swale Layout**: Using a measuring tape, mark the areas where you plan to dig the swale. Typically, a swale should be dug on the contour line-where the land is level-to maximize water capture. The swale should be positioned at least 10 feet away from your foundation to prevent water from seeping into the basement.
3. **Determine Swale Dimensions**: A standard swale is about 18 inches deep and 2-3 feet wide at the top, tapering to a point at the bottom. The depth can vary depending on the slope and soil type. Ensure the swale is deep enough to hold the volume of water you

expect it to manage.

4. **Excavate the Swale**: Using a shovel or excavator, begin digging along the marked contour line. Remove the topsoil and set it aside for backfilling later. Aim for a gentle slope on both sides of the swale to encourage water to flow into it naturally.
5. **Line the Swale (Optional)**: If you're concerned about soil erosion or want to enhance water infiltration, consider lining the swale with landscape fabric or a geotextile membrane. This will help prevent soil from washing away while allowing water to permeate through.
6. **Install Drainage Structures**: To ensure efficient water flow, incorporate drainage structures such as perforated pipes or gravel-filled trenches at the bottom of the swale. These will help direct water away from your foundation and towards a designated discharge area, such as a dry well or storm drain.
7. **Backfill and Shape**: Once the swale is excavated and any drainage structures are in place, begin backfilling with the topsoil you set aside. Shape the swale so that it has a slight crown in the center to facilitate water flow. Use a rake to smooth out the surface.
8. **Plant Vegetation**: To stabilize the swale and enhance its aesthetic appeal, plant native grasses, shrubs, or ground cover along the swale. Choose plants that are drought-tolerant and can handle periodic flooding. This vegetation will help bind the soil and reduce erosion.
9. **Maintain the Swale**: Regular maintenance is crucial to ensure your swale remains effective. Check for any blockages in the drainage structures, remove debris, and monitor plant growth. Trim back any overgrown vegetation to prevent it from obstructing water flow.

By following these steps, you can design and install a swale that effectively controls water flow around your residential foundation, protecting your home from water damage and enhancing the overall landscape.

Case studies or examples of successful swale installations in residential settings for foundation repair.

Certainly!

Understanding the effective placement of swales in residential settings for foundation repair is crucial for homeowners looking to manage water flow around their properties. Swales, which are shallow, vegetated ditches, play a pivotal role in directing water away from foundations, thereby preventing water damage and erosion. Let's delve into some case studies and examples of successful swale installations that highlight their benefits and effectiveness.

One notable example is the case of a suburban home in the Pacific Northwest, where heavy

rainfall was causing significant issues with the foundation. The homeowners decided to install a swale system along the perimeter of their property. The swale was designed with a gentle slope, leading water away from the house and towards a designated drainage area. Over time, this system effectively reduced water accumulation around the foundation, significantly mitigating the risk of water damage. Additionally, the vegetation within the swale absorbed excess water, further enhancing its effectiveness.

Another compelling case study comes from a residential area in the Midwest, where a series of homes were experiencing foundation issues due to poor water drainage. A community-wide initiative was launched to install swale systems across multiple properties. The swales were strategically placed to intercept rainwater before it could reach the foundations. This collective approach not only improved individual properties but also enhanced the overall water management of the neighborhood. The success of this project was evident in the reduced instances of foundation repairs and the improved landscape aesthetics.

In a more urban setting, a townhouse complex in the Northeast faced challenges with water pooling near the foundations during heavy rains. The management company decided to implement a swale system integrated with rain gardens. These rain gardens, which are essentially enhanced swales with specific plant selections, provided additional water absorption and filtration. The results were remarkable; not only did the swales prevent water from undermining the foundations, but they also contributed to a more sustainable urban environment by reducing stormwater runoff.

These examples underscore the importance of understanding swale placement for controlled water flow. When designed and installed correctly, swales can be a highly effective solution for foundation repair and water management in residential settings. They offer a natural, aesthetically pleasing alternative to traditional drainage systems, while also providing environmental benefits such as water filtration and habitat creation. For homeowners considering swale installation, these case studies serve as valuable illustrations of the potential benefits and successful outcomes that can be achieved with thoughtful planning and execution.

Tips for maintaining and monitoring swales to ensure they continue to effectively manage water flow and protect the foundation.

Certainly! Maintaining and monitoring swales is crucial to ensure their effectiveness in managing water flow and safeguarding the foundation of a property. Here are some practical tips to keep your swales in top condition.

Firstly, regular inspections are key. Check your swales at least once a month, especially after heavy rains, to look for any signs of erosion, sedimentation, or blockages. Clearing out debris such as leaves, branches, and other obstructions is essential to maintain smooth water flow. This not only helps in preventing water from backing up but also ensures that the swale continues to function as intended.

Another important aspect is to monitor the vegetation within and around the swale. Healthy

vegetation plays a vital role in stabilizing the soil and enhancing water infiltration. Ensure that the plants are thriving and replace any that may have died. Additionally, avoid planting invasive species that could outcompete native plants and disrupt the ecosystem.

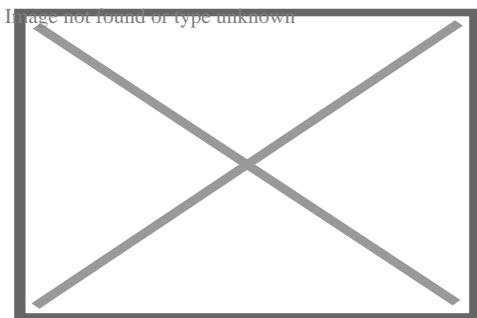
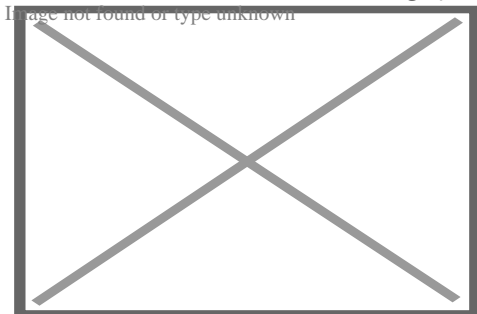
It's also beneficial to create a buffer zone around the swale. This can be achieved by planting a mix of grasses, shrubs, and trees that help in absorbing excess water and reducing runoff. The buffer zone acts as an additional layer of protection, enhancing the swale's ability to manage water flow effectively.

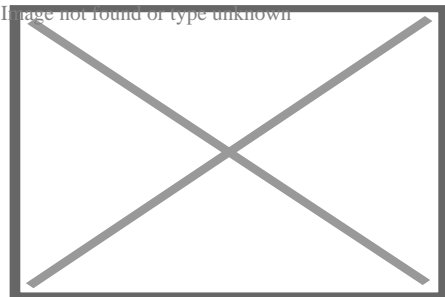
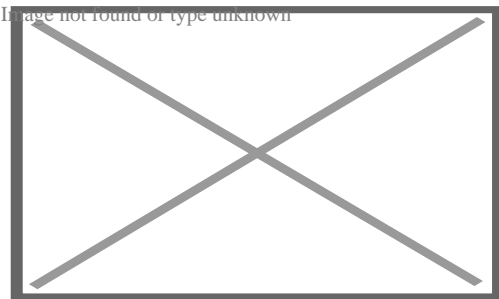
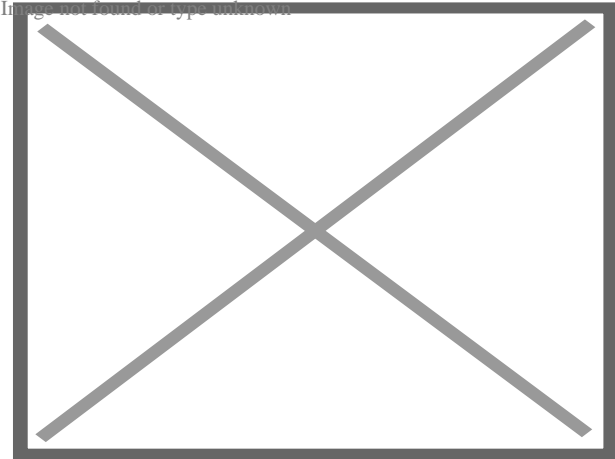
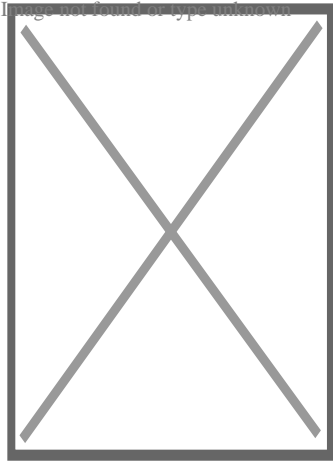
Lastly, consider the impact of human activities on the swale. Avoid compacting the soil around the swale by minimizing foot traffic and vehicle use in the area. Compacted soil can reduce water infiltration and compromise the swale's functionality.

By following these tips, you can ensure that your swales remain effective in controlling water flow and protecting your foundation for years to come. Regular maintenance and mindful monitoring are the keys to successful swale management.

About ceiling

For other uses, see [Ceiling](#) (disambiguation).





Various examples of ornate ceilings

A **ceiling** /ˈsiːlɪŋ/ is an overhead interior roof that covers the upper limits of a room. It is not generally considered a structural element, but a finished surface concealing the underside of the roof structure or the floor of a story above. Ceilings can be decorated to taste, and there are many examples of frescoes and artwork on ceilings, especially within religious buildings. A ceiling can also be the upper limit of a tunnel.

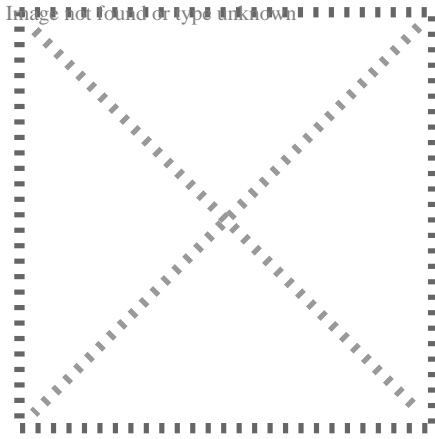
The most common type of ceiling is the dropped ceiling, ^[*citation needed*] which is suspended from structural elements above. Panels of drywall are fastened either directly to the ceiling joists or to a few layers of moisture-proof plywood which are then attached to the joists. Pipework or ducts can be run in the gap above the ceiling, and insulation and fireproofing material can be placed here. Alternatively, ceilings may be spray painted instead, leaving the pipework and ducts exposed but painted, and using spray foam.

A subset of the dropped ceiling is the suspended ceiling, wherein a network of aluminum struts, as opposed to drywall, are attached to the joists, forming a series of rectangular spaces. Individual pieces of cardboard are then placed inside the bottom of those spaces so that the outer side of the cardboard, interspersed with aluminum rails, is seen as the ceiling from below. This makes it relatively easy to repair the pipes and insulation behind the ceiling, since all that is necessary is to lift off the cardboard, rather than digging through the drywall and then replacing it.

Other types of ceiling include the cathedral ceiling, the concave or barrel-shaped ceiling, the stretched ceiling and the coffered ceiling. Coving often links the ceiling to the surrounding walls. Ceilings can play a part in reducing fire hazard, and a system is available for rating the fire resistance of dropped ceilings.

Types

[edit]



California tract home with an open-beam ceiling, 1960

Ceilings are classified according to their appearance or construction. A cathedral ceiling is any tall ceiling area similar to those in a church. A dropped ceiling is one in which the finished surface is constructed anywhere from a few inches or centimeters to several feet or a few meters below the structure above it. This may be done for aesthetic purposes, such as achieving a desirable ceiling height; or practical purposes such as acoustic damping or providing a space for HVAC or piping. An inverse of this would be a raised floor. A concave or barrel-shaped ceiling is curved or rounded upward, usually for visual or acoustical value,

while a coffered ceiling is divided into a grid of recessed square or octagonal panels, also called a "lacunar ceiling". A cove ceiling uses a curved plaster transition between wall and ceiling; it is named for cove molding, a molding with a concave curve.^[1] A stretched ceiling (or stretch ceiling) uses a number of individual panels using material such as PVC fixed to a perimeter rail.^[2]

Elements

[edit]

Ceilings have frequently been decorated with fresco painting, mosaic tiles and other surface treatments. While hard to execute (at least in place) a decorated ceiling has the advantage that it is largely protected from damage by fingers and dust. In the past, however, this was more than compensated for by the damage from smoke from candles or a fireplace. Many historic buildings have celebrated ceilings. Perhaps the most famous is the Sistine Chapel ceiling by Michelangelo.

Ceiling height, particularly in the case of low ceilings, may have psychological impacts. ^[3]

Fire-resistance rated ceilings

[edit]

The most common ceiling that contributes to fire-resistance ratings in commercial and residential construction is the dropped ceiling. In the case of a dropped ceiling, the rating is achieved by the entire system, which is both the structure above, from which the ceiling is suspended, which could be a concrete floor or a timber floor, as well as the suspension mechanism and, finally the lowest membrane or dropped ceiling. Between the structure that the dropped ceiling is suspended from and the dropped membrane, such as a T-bar ceiling or a layer of drywall, there is often some room for mechanical and electrical piping, wiring and ducting to run.

An independent ceiling, however, can be constructed such that it has a stand-alone fire-resistance rating. Such systems must be tested without the benefit of being suspended from a slab above in order to prove that the resulting system is capable of holding itself up. This type of ceiling would be installed to protect items above from fire.

An unrestrained non-loadbearing ceiling undergoing a 4-hour fire test. Deflection is measured off the I-beam.

○

Image not found or type unknown

An unrestrained non-loadbearing ceiling undergoing a 4-hour fire test. Deflection is measured off the I-beam.

○ Durasteel ceiling after successful fire test, being raised from the furnace and readied for an optional 45PSI (3.1 bar) hose-stream test.

Image not found or type unknown

Durasteel ceiling after successful fire test, being raised from the furnace and readied for an optional 45PSI (3.1 bar) hose-stream test.

Gallery

[edit]

○ Gothic ceiling in the Sainte-Chapelle, Paris, 1243-1248, by Pierre de Montreuil^[4]

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Gothic ceiling in the Sainte-Chapelle, Paris, 1243-1248, by Pierre de Montreuil^[4]

Renaissance ceiling of the Henry II staircase in the Louvre Palace, Paris, by Étienne Carmoy

○

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Renaissance
ceiling of the
Henry II
staircase in the
Louvre Palace,
Paris, by
Étienne
Carmoy,
Raymond
Bidollet, Jean
Chrestien and
François
Lheureux, 1553
[⁵]

Renaissance ceiling of the king's bedroom in the Louvre Palace, by Francisque Scibecq de Carpi

○

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Renaissance
ceiling of the king's
bedroom in the
Louvre Palace, by
Francisque
Scibecq de Carpi,
1556[⁶]

- Baroque ceiling of the Salle des Saisons in the Louvre Palace, by Giovanni Francesco Romanelli

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Baroque
ceiling of the
Salle des
Saisons in the
Louvre
Palace, by
Giovanni
Francesco
Romanelli,
Michel
Anguier and
Pietro Sasso,
mid 17th
century^[7]

- Neoclassical ceiling of the Salle Duchâtel in the Louvre Palace, with The Triumph of French Painting.

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Neoclassical
ceiling of the
Salle Duchâtel in
the Louvre
Palace, with The
Triumph of
French Painting.
Apotheosis of
Poussin, Le
Sueur and Le

Brun in the
centre, by
Charles Meynier,
1822, and
ceilings panels
with medallion
portraits of
French painters,
1828-1833^[8]

- Neoclassical ceiling of the Mollien staircase in the Louvre Palace, designed by Hector Lefuel in

Image not found or type unknown

Neoclassical ceiling of the Mollien
staircase in the Louvre Palace,
designed by Hector Lefuel in 1857 and
painted by Charles Louis Müller in
1868-1870^[9]

Moorish Revival ceiling in the Nicolae T. Filitti/Nae Filitis House (Calea DorobanÈilor no. 18), B

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Moorish Revival ceiling in the
Nicolae T. Filitti/Nae Filitis House
(Calea DorobanÈilor no. 18),
Bucharest, Romania, de Ernest
Doneaud, c.1910^[10]

Demonstrative reconstruction of a Roman suspended ceiling in an Imperial palace of circa AD 306

○

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Demonstrative reconstruction of a Roman suspended ceiling in an Imperial palace of circa AD 306 at Trier, Italy

○ Part of the ceiling of the Sistine Chapel in Vatican City in Rome, showing the ceiling in relation to the other frescoes

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Part of the ceiling of the Sistine Chapel in Vatican City in Rome, showing the ceiling in relation to the other frescoes

Ceiling of the Villa Schutzenberger from Strasbourg, France, decorated with Art Nouveau ornaments

○

Image not found or type unknown

Ceiling of the Villa Schutzenberger from Strasbourg, France, decorated with Art Nouveau ornaments

- Painted ceiling in Liège, Belgium

Image not found or type unknown

**Painted ceiling in
Liège, Belgium**

- Traditional Chinese ceiling of Dayuan Renshou Temple at Taoyuan, Taiwan

Image not found or type unknown

**Traditional Chinese ceiling of
Dayuan Renshou Temple at
Taoyuan, Taiwan**

- Dropped ceiling

Image not found or type unknown

Dropped ceiling

- Wooden beam ceiling

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Wooden beam ceiling

See also

[edit]

- Beam ceiling
- Hammerbeam roof
- Hollow-core slab
- Moulding (decorative)
- Popcorn ceiling
- Scottish Renaissance painted ceilings
- Tin ceiling
- Passive fire protection
- Fire test
- Hy-Rib


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External links

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Look up ***ceiling*** in Wiktionary, the free dictionary.

-  Media related to Ceilings at Wikimedia Commons
- o "*Ceiling*". *Encyclopædia Britannica. Vol. 5 (11th ed.)*. 1911.
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- o v
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Rooms and spaces of a house

- o Bonus room
- o Common room
- o Den
- o Dining room
- o Family room
- o Garret
- o Great room
- o Home cinema
- o Kitchen
 - o dirty kitchen
 - o kitchenette
- o Living room
- o Gynaecium
 - o harem
- o Andron
 - o man cave
- o Recreation room
 - o billiard room
- o Shrine
- o Study
- o Sunroom

Shared rooms

Private rooms

- Bathroom
 - toilet
- Bedroom / Guest room
 - closet
- Bedsit / Miniflat
- Boudoir
- Cabinet
- Nursery

Spaces

- Atrium
- Balcony
- Breezeway
- Conversation pit
- Cubby-hole
- Deck
- Elevator
 - dumbwaiter
- Entryway/Genkan
- Fireplace
 - hearth
- Foyer
- Hall
- Hallway
- Inglenook
- Lanai
- Loft
- Loggia
- Overhang
- Patio
- Porch
 - screened
 - sleeping
- Ramp
- Secret passage
- Stairs/Staircase
- Terrace
- Veranda
- Vestibule

**Technical, utility
and storage**

- Attic
- Basement
- Carport
- Cloakroom
- Closet
- Crawl space
- Electrical room
- Equipment room
- Furnace room / Boiler room
- Garage
- Janitorial closet
- Larder
- Laundry room / Utility room / Storage room
- Mechanical room / floor
- Pantry
- Root cellar
- Semi-basement
- Storm cellar / Safe room
- Studio
- Wardrobe
- Wine cellar
- Wiring closet
- Workshop

Great house areas

- Antechamber
- Ballroom
- Kitchen-related
 - butler's pantry
 - buttery
 - saucery
 - scullery
 - spicery
 - still room
- Conservatory / Orangery
- Courtyard
- Drawing room
- Great chamber
- Great hall
- Library
- Long gallery
- Lumber room
- Parlour
- Sauna
- Servants' hall
- Servants' quarters
- Smoking room
- Solar
- State room
- Swimming pool
- Turret
- Undercroft

Other

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- Terraced
- Detached
- Semi-detached
- Townhouse
- Studio apartment

**Architectural
elements**

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- Baluster
- Belt course
- Bressummer
- Ceiling
- Chimney
- Colonnade / Portico
- Column
- Cornice / Eaves
- Dome
- Door
- Ell
- Floor
- Foundation
- Gable
- Gate
 - Portal
- Lighting
- Ornament
- Plumbing
- Quoins
- Roof
 - shingles
- Roof lantern
- Sill plate
- Style
 - list
- Skylight
- Threshold
- Transom
- Vault
- Wall
- Window

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- Front yard
- Garden
 - roof garden
- Home
- Home improvement
- Home repair
- Shed
- Tree house

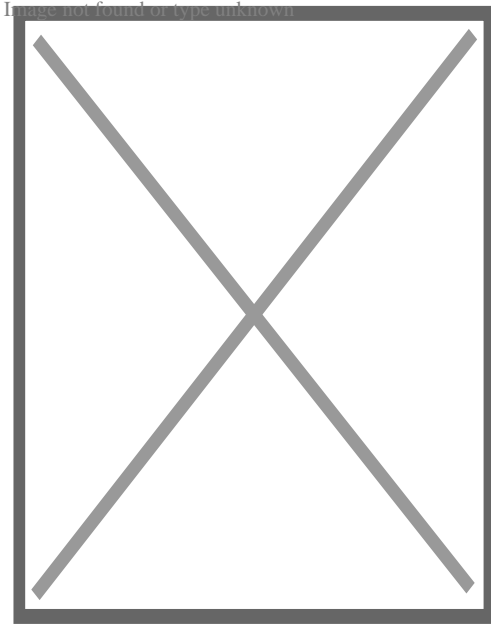
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- United States
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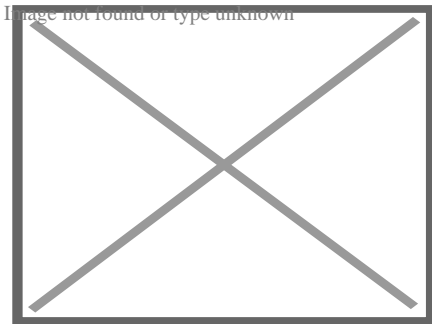
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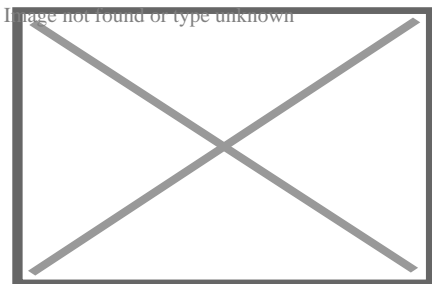
About geotechnical engineering



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 the frictional stress, $\sigma \tan(\phi)$, 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

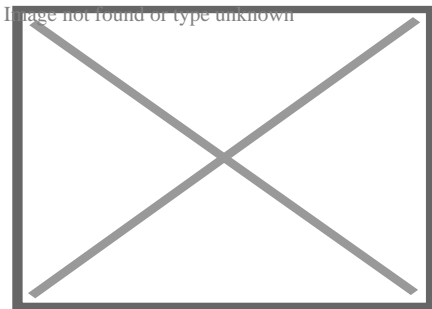
[edit]

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.

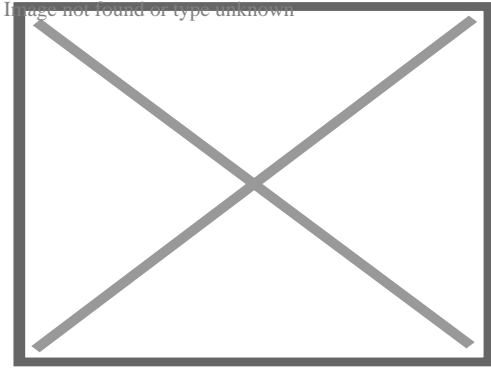
Ground improvement

[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.

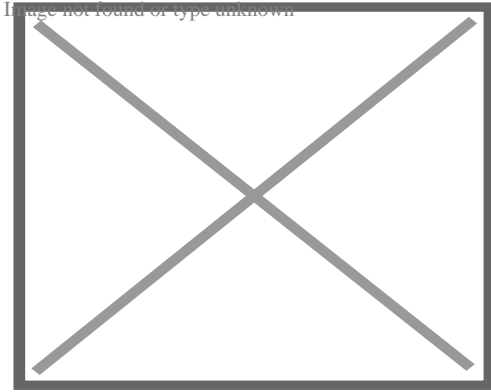
Sub-disciplines

[edit]

Geosynthetics

[edit]

Main article: Geosynthetics



A collage of geosynthetic products.

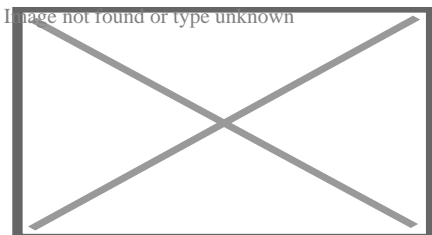
Geosynthetics are a type of plastic polymer products used in geotechnical engineering that improve engineering performance while reducing costs. This includes geotextiles, geogrids, geomembranes, geocells, and geocomposites. The synthetic nature of the products make them suitable for use in the ground 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]

 [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]

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External links

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- Worldwide Geotechnical Literature Database
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Engineering

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- o Outline
- o List of engineering branches

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- 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

Electrical

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

**Specialties
and
interdisciplinarity**

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Engineering education

- Bachelor of Engineering
- Bachelor of Science
- Master's degree
- Doctorate
- Graduate certificate
- Engineer's degree
- Licensed engineer

Related topics

- Engineer

Glossaries

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 - M–Z
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- Civil engineering
- Electrical and electronics engineering
- Mechanical engineering
- Structural engineering

Other

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- Automation
- Biomedical
 - Bioinformatics
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 - Pharmaceutical
 - Rehabilitation
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 - MEP
- Design
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- Nuclear
- Ontology
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- Physics
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- Systems
- Textile

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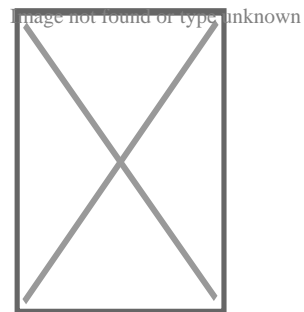
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Soil science

- 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)

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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

- Alfisols
- Andisols
- Aridisols
- Entisols
- Gelisols
- Histosols

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

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-  [Category soil](#)
- [Category soil science](#)
-  [List of soil scientists](#)





















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- **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

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

Forces

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

Mechanics

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

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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

- 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

Other topics

 [Outline](#)  [Category](#)

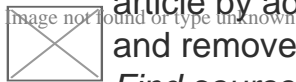
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About radon mitigation

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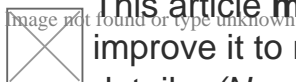


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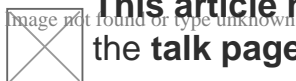
The examples and perspective in this article **deal primarily with North America and Globe** **do not represent a worldwide view of the subject**. You may improve this article, **discuss the issue** on the talk page, or create a new article, as appropriate. *(June 2019)* *(Learn how and when to remove this message)*



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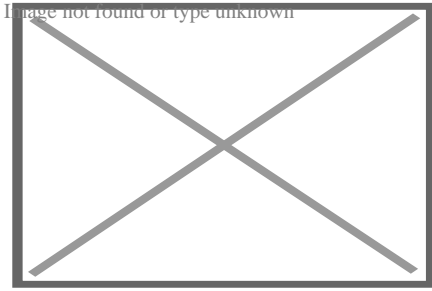
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Radon mitigation is any process used to reduce radon gas concentrations in the breathing zones of occupied buildings, or radon from water supplies. Radon is a significant contributor to environmental radioactivity and indoor air pollution. Exposure to radon can cause serious health problems such as lung cancer.^[1]

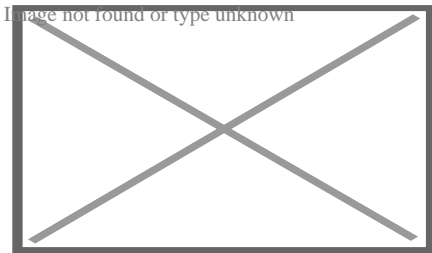
Mitigation of radon in the air by active soil depressurization is most effective. Concrete slabs, sub-floors, and/or crawlspaces are sealed, an air pathway is then created to exhaust radon above the roof-line, and a radon mitigation fan is installed to run permanently. In particularly troublesome dwellings, air exchangers can be used to reduce indoor radon concentrations. Treatment systems using aeration or activated charcoal are available to remove radon from domestic water supplies. There is no proven link between radon in water and gastrointestinal cancers; however, extremely high radon concentrations in water can be aerosolized by faucets and shower heads and contribute to high indoor radon levels in the air.

Testing

[edit]



A typical radon test kit



Fluctuation of ambient air radon concentration over one week, measured in a laboratory

The first step in mitigation is testing. No level of radiation is considered completely safe, but as it cannot be eliminated, governments around the world have set various *action levels* to provide guidance on when radon concentrations should be reduced. The World Health Organization's International Radon Project has recommended an action level of 100 Bq/m^3 (2.7 pCi/L) for radon in the air.^[2] Radon in the air is considered to be a larger health threat than radon in domestic water. The US Environmental Protection Agency recommendation is to not test for radon in water unless a radon in air test shows concentrations above the action level. However, in some U.S. states such as Maine where radon levels are higher than the national average, it is recommended that all well water should be tested for radon. The U.S. government has not set an action level for radon in water.

Air-radon levels fluctuate naturally on a daily and seasonal basis. A short term test (90 days or less) might not be an accurate assessment of a home's average radon level, but is recommended for initial testing to quickly determine unhealthy conditions. Transient weather such as wind and changes in barometric pressure can affect short-term concentrations as well as ventilation, such as open windows and the operation of exhaust fans.

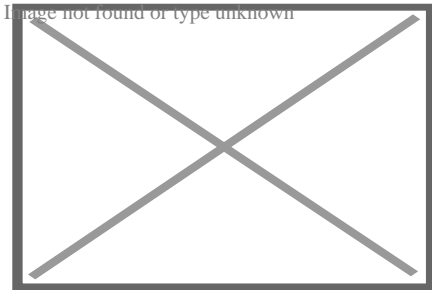
Testing for radon in the air is accomplished using passive or active devices placed in the building. Some devices are promptly sent to a laboratory for analysis, others calculate the results on-site including digital Radon detectors. Radon-in-water testing requires a water sample being sent to a laboratory.

Retesting is recommended in several situations, for example, before spending money on the installation of a mitigation system. Test results which exceed accuracy tolerances also require re-testing. When a mitigation system installation is warranted, a retest after the system is functional is advised to be sure the system is effectively reducing the radon concentration

below the action level, and after any mitigation system repairs such as replacing a fan unit. The US EPA recommends retesting homes with radon problems every two years to ensure proper system function. Due to the vast fluctuation in indoor radon levels, the EPA recommends all homes be tested at least once every five years.^[3]

Testing in the United States

[edit]



Radon map of the United States

ASTM E-2121 is a US standard for reducing airborne radon in homes as far as practicable below the action level of 4 picocuries per liter (pCi/L) (148 Bq/m³).^{[4][5]} Some states recommend achieving 2.0 pCi/L or less.

Radon test kits are commercially available^[6] and can be used by homeowners and tenants and in limited cases by landlords, except when a property is for sale.

Commercially available test kits include a passive collector that the user places in the lowest livable floor of the house for 2 to 7 days. The user then sends the collector to a laboratory for analysis. Long-term kits, taking collections from 91 days to one year, are also available. Open land test kits can test radon emissions from the land before construction begins, but are not recommended by the EPA because they do not accurately predict the final indoor radon level. The EPA and the National Environmental Health Association have identified 15 types of radon test devices.^[7] A Lucas cell is one type of device.

Retesting is specifically recommended in several situations. Measurements between 4 and 10 pCi/L (148 and 370 Bq/m³) warrant a follow-up short-term or long-term radon test before mitigation. Measurements over 10 pCi/L (370 Bq/m³) warrant only another short-term test (not a long-term test) so that abatement measures are not unduly delayed.

Progress has been made regarding radon in the home. A total of 37 states have now^[when?] passed legislation requiring home-sellers to disclose known radon levels before completing the transaction (although only a handful have introduced criminal penalties for misrepresentation).^[8] And over half the legislatures have written radon into their state's

building code.^[9] Purchasers of real estate may delay or decline a purchase if the seller has not successfully abated radon to less than 4 pCi/L.

The accuracy of the residential radon test depends upon whether closed house conditions are maintained. Thus the occupants will be instructed not to open windows, etc., for ventilation during the pendency of test, usually two days or more. However, the occupants, if the present owners, will be motivated to pass the test and insure the sale, so they might be tempted to open a window to get a lower radon score. Moreover, there may be children or immature teens or young adults in the house who will open a window for ventilation notwithstanding instructions not to do so, particularly in uncomfortably hot weather. Accordingly, whether the potential purchaser should trust the result of such a test is problematic.

Management of radon service provider certification has evolved since being introduced by the EPA in 1986. In the 1990s this service was "privatized" and the National Environmental Health Association (NEHA) helped transition the voluntary National Radon Proficiency Program (NRPP) to be administered by private firms. As of 2012, the NRPP is administered by the American Association of Radon Scientists and Technologists (AARST).^[10]

Some states, such as Maine, require landlords to test their rental properties and turn the results in to the state. In limited cases the landlord or tenants may do the testing themselves. The rules in each state vary. In many cases there are private contractors that will inspect hired by the city.

Testing in Canada

[edit]

Health Canada recommends regular annual testing, either by hiring a qualified tester or by using a home-testing kit that should be checked quarterly.^[11]

Canadian Government, in conjunction with the territories and provinces, developed the guideline^[12] to indicate when remedial action should be taken was originally set at 800 Bq/m³ (becquerels per cubic meter) and since reduced to 200 Bq/m³. This new guideline was approved by the Federal Provincial Territorial Radiation Protection Committee in October 2006.^[13]

Testing in the UK

[edit]

Radon testing in the UK is managed by UKradon and the UKHSA.^[14]

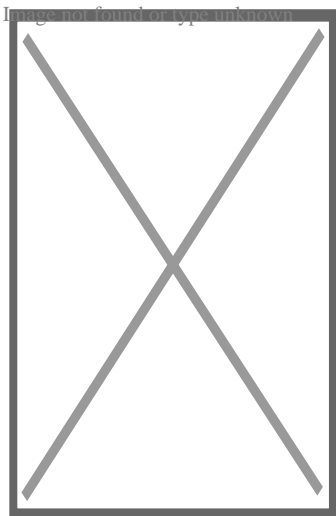
Testing in Norway

[edit]

The Norwegian Radiation and Nuclear Safety Authority (DSA) developed the protocol^[15] for radon measurements in residential dwellings^[16] with respect to rental accommodation, which is governed by The Radiation Protection Regulations.^[17]

Methods of radon gas mitigation

[edit]



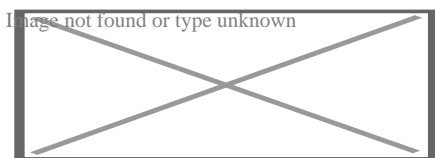
Part of a radon mitigation system including the fan and vent pipe is visible near the gutter downspout.

Because high levels of radon have been found in every state of the United States,^[18] testing for radon and installing radon mitigation systems has become a specialized industry since the 1980s. Many states have implemented programs that affect home buying and awareness in the real estate community; however, radon testing and mitigation systems are not generally mandatory unless specified by the local jurisdiction.^[19]

Anticipated high radon levels can be mitigated during building design and construction by a combination of ensuring a perfectly sealed foundation, allowing sufficient passive dispersal of under-slab gas around rather than through the building, and proper building ventilation. In many instances, such approaches may achieve a sufficient reduction of radon levels

compared to other buildings where such approaches were not taken. However, quality of implementation is crucial and testing after construction is necessary. For instance, even a small gap in the sealing of the slab may be sufficient for excessive quantities of radon to enter, given pressure differentials.

Where such approaches were not taken during construction or have proven insufficiently effective, remediation is needed. According to the EPA's "A Citizen's Guide to Radon",^[20] the method to reduce radon "primarily used is a vent pipe system and fan, which pulls radon from beneath the house and vents it to the outside", which is also called sub-slab depressurization, soil suction, or active soil depressurization (ASD). Generally indoor radon can be mitigated by sub-slab depressurization and exhausting such radon-laden air to the outdoors, away from windows and other building openings.^[21] "EPA generally recommends methods which prevent the entry of radon. Soil suction, for example, prevents radon from entering your home by drawing the radon from below the home and venting it through a pipe, or pipes, to the air above the home where it is quickly diluted" and "EPA does not recommend the use of sealing alone to reduce radon because, by itself, sealing has not been shown to lower radon levels significantly or consistently" according to the EPA's "Consumer's Guide to Radon Reduction: How to Fix Your Home".^[22] Ventilation systems can utilize a heat exchanger or energy recovery ventilator to recover part of the energy otherwise lost in the process of exchanging air with the outside. For crawlspaces, the EPA states,^[22] "An effective method to reduce radon levels in crawlspace homes involves covering the earth floor with a high-density plastic sheet. A vent pipe and fan are used to draw the radon from under the sheet and vent it to the outdoors. This form of soil suction is called submembrane suction, and when properly applied is the most effective way to reduce radon levels in crawlspace homes."



High radon levels in a Minnesota (USA) basement with a passive under slab vent pipe system can be seen in the left half of the graph. After installation of a radon fan (ASD), a permanent reduction in radon levels to approximately 0.6 pCi/L can be seen in the right half of the graph.

- The most common approach is active soil depressurization (ASD). Experience has shown that ASD is applicable to most buildings since radon usually enters from the soil and rock underneath and mechanical ventilation is used when the indoor radon is emitted from the building materials. A less common approach works efficiently by reducing air pressures within cavities of exterior and demising walls where radon emitting from building materials, most often concrete blocks, collects.
- Above slab air pressure differential barrier technology (ASAPDB) requires that the interior pressure envelope, most often drywall, as well as all ductwork for air conditioning systems, be made as airtight as possible. A small blower, often no more than 15 cubic

feet per minute (0.7 L/s) may then extract the radon-laden air from these cavities and exhaust it to the out of doors. With well-sealed HVAC ducts, very small negative pressures, perhaps as little as 0.5 pascal (0.00007 psi), will prevent the entry of highly radon-laden wall cavity air from entering into the breathing zone. Such ASAPDB technology is often the best radon mitigation choice for high-rise condominiums as it does not increase indoor humidity loads in hot humid climates, and it can also work well to prevent mold growth in exterior walls in heating climates.

- In hot, humid climates, heat recovery ventilators (HRV) as well as energy recovery ventilators (ERV) have a record of increasing indoor relative humidity and dehumidification demands on air conditioning systems. Mold problems can occur in homes that have been radon mitigated with HRV and ERV installations in hot, humid climates.^[citation needed] HRVs and ERVs have an excellent record in cold dry climates.
- A recent technology is based on building science. It includes a variable rate mechanical ventilation system that prevents indoor relative humidity from rising above a preset level such as 50% which is currently suggested by the US Environmental Protection Agency and others as an upper limit for the prevention of mold. It has proven to be especially effective in hot, humid climates. It controls the air delivery rate so that the air conditioner is never overloaded with more moisture than it can effectively remove from the indoor air.
 - It is generally assumed that air conditioner operation will remove excess moisture from the air in the breathing zone, but it is important to note that just because the air conditioner cools does not mean that it is also dehumidifying. If Δt is 14 degrees or less, it may not dehumidify at all even though it is cooling.
 - Factors that are likely to aggravate indoor humidity problems from mechanical ventilation-based radon installations are as follows and an expert radon mitigator/building scientist will check for and correct any and all of the following when he or she performs radon mitigation procedures:
 - Air conditioner duct leaks located outside the breathing zone, such as in the attic.
 - Excessive exhaust fan operation
 - Oversize or over-capacity air conditioners
 - AC air handler fans that do not stop running when the air conditioner compressor stops running.
 - Delta t (Δt), which is the amount that the air is cooled as it is passed through the air conditioner's cooling coils. A good Δt performance figure for home air conditioners is about 20 °F (11 °C). In comparison, automobile air conditioners deliver Δt performance of 32 to 38 °F (18 to 21 °C). A Δt of 14 °F (8 °C) will dehumidify poorly if at all.

In South Florida, most radon mitigation is performed by use of fixed rate mechanical ventilation. Radon mitigation training in Florida does not include problems associated with mechanical ventilation systems, such as high indoor humidity, mold, moldy odors, property

damage or health consequences of human occupation in high humidity of moldy environments^[citation needed]. As a result, most Florida radon mitigators are unaware of and do not incorporate existing building science moisture management technology into mechanical ventilation radon installations. Home inspectors may not necessarily be aware of the mold risks associated with radon mitigation by mechanical ventilation.

The average cost for an ASD radon mitigation system in Minnesota is \$1500.^[23] These costs are very dependent on the type of home and age of construction.^[24]

Methods of radon-in-water mitigation

[edit]

Radon removal from water supplies may be at a treatment plant, point of entry, or point of use. Public water supplies in the United States were required to treat for radionuclides beginning in 2003 but private wells are not regulated by the federal government as of 2014. The radon can be captured by granular activated charcoal (GAR) or released into the air through aeration of the water. Radon will naturally dissipate from water over a period of days, but the quantity of storage needed to treat the water in this manner makes home systems of this type impracticably large.^[25]

Activated carbon systems capture radon from the water. The amount of radiation accumulates over time and the filter material may reach the level of requiring disposal as a radioactive waste. However, in the United States there are no regulations concerning radiation levels and disposal of radon treatment waste as of 2014.

Aeration systems move the radon from the water to the air. Radon gas discharged into the air is the release of a pollutant, and may become regulated in the United States.

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[edit]

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- [^] WHO Handbook on Indoor Radon: A Public Health Perspective. World Health Organization. 2009.
- [^] US EPA, OAR (2013-08-27). "Radon". www.epa.gov. Retrieved 2023-02-04.
- [^] "Recommended Residential Radon Mitigation Standard of Practice". United States Environmental Protection Agency. Archived from the original on 2008-01-16. Retrieved 2008-02-02.
- [^] "ASTM E2121-03 Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings". ASTM International. Retrieved 2008-02-02.

6. ^ *"Commercially Available Radon Kits". Alpha Energy Labs. Archived from the original on 2012-07-12. Retrieved 2012-04-19.*
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19. ^ *"Listing of States and Jurisdictions with RRNC Codes". EPA. Retrieved 2009-11-13.*
20. ^ *"A Citizen's Guide to Radon" (PDF). EPA. Retrieved 2024-12-27.*
21. ^ *"Radon Mitigation Methods". Radon Solution. Archived from the original on 2008-12-15. Retrieved 2008-12-02.*
22. ^ **a b** *"Consumer's Guide to Radon Reduction: How to Fix Your Home" (PDF). EPA.*
23. ^ *"Radon Mitigation System - EH: Minnesota Department of Health". Health.state.mn.us. 2014-12-10. Retrieved 2019-03-26.*
24. ^ *"Featured Radon Mitigation System Archives". Radonreductioninc.com. Retrieved 2015-03-30.*
25. ^ *"Radon in Drinking Water Health Risk Reduction and Cost Analysis: Notice" (PDF). Federal Register. **64**. February 26, 1999. Retrieved 2015-03-30.*

External links

[edit]

- Radon at the United States Environmental Protection Agency
- National Radon Program Services hosted by Kansas State University
- Radon and Lung Health from the American Lung Association
- It's Your Health - Health Canada
- Radon's impact on your health – Quebec Lung Association

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Radiation protection

Main articles

- o Background radiation
- o Dosimetry
- o Health physics
- o Ionizing radiation
- o Internal dosimetry
- o Radioactive contamination
- o Radioactive sources
- o Radiobiology

Measurement quantities and units

- o Absorbed dose
- o Becquerel
- o Committed dose
- o Computed tomography dose index
- o Counts per minute
- o Effective dose
- o Equivalent dose
- o Gray
- o Mean glandular dose
- o Monitor unit
- o Rad
- o Roentgen
- o Rem
- o Sievert

Instruments and measurement techniques

- o Airborne radioactive particulate monitoring
- o Dosimeter
- o Geiger counter
- o Ion chamber
- o Scintillation counter
- o Proportional counter
- o Radiation monitoring
- o Semiconductor detector
- o Survey meter
- o Whole-body counting

- Protection techniques**
 - Lead shielding
 - Glovebox
 - Potassium iodide
 - Radon mitigation
 - Respirators

- Organisations**
 - Euratom
 - HPS (USA)
 - IAEA
 - ICRU
 - ICRP
 - IRPA
 - SRP (UK)
 - UNSCEAR

- Regulation**
 - IRR (UK)
 - NRC (USA)
 - ONR (UK)
 - Radiation Protection Convention, 1960

- Radiation effects**
 - Acute radiation syndrome
 - Radiation-induced cancer

See also the categories Medical physics, Radiation effects, Radioactivity, Radiobiology, and Radiation protection

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Heating, ventilation, and air conditioning

**Fundamental
concepts**

- Air changes per hour (ACH)
- Bake-out
- Building envelope
- Convection
- Dilution
- Domestic energy consumption
- Enthalpy
- Fluid dynamics
- Gas compressor
- Heat pump and refrigeration cycle
- Heat transfer
- Humidity
- Infiltration
- Latent heat
- Noise control
- Outgassing
- Particulates
- Psychrometrics
- Sensible heat
- Stack effect
- Thermal comfort
- Thermal destratification
- Thermal mass
- Thermodynamics
- Vapour pressure of water

- Absorption-compression heat pump
- Absorption refrigerator
- Air barrier
- Air conditioning
- Antifreeze
- Automobile air conditioning
- Autonomous building
- Building insulation materials
- Central heating
- Central solar heating
- Chilled beam
- Chilled water
- Constant air volume (CAV)
- Coolant
- Cross ventilation
- Dedicated outdoor air system (DOAS)
- Deep water source cooling
- Demand controlled ventilation (DCV)
- Displacement ventilation
- District cooling
- District heating
- Electric heating
- Energy recovery ventilation (ERV)
- Firestop
- Forced-air
- Forced-air gas
- Free cooling
- Heat recovery ventilation (HRV)
- Hybrid heat
- Hydronics
- Ice storage air conditioning
- Kitchen ventilation
- Mixed-mode ventilation
- Microgeneration
- Passive cooling
- Passive daytime radiative cooling
- Passive house
- Passive ventilation
- Radiant heating and cooling
- Radiant cooling
- Radiant heating
- Radon mitigation
- Refrigeration
- Renewable heat
- Room air distribution
- Solar air heat
- Solar combisystem

Technology

- Air conditioner inverter
- Air door
- Air filter
- Air handler
- Air ionizer
- Air-mixing plenum
- Air purifier
- Air source heat pump
- Attic fan
- Automatic balancing valve
- Back boiler
- Barrier pipe
- Blast damper
- Boiler
- Centrifugal fan
- Ceramic heater
- Chiller
- Condensate pump
- Condenser
- Condensing boiler
- Convection heater
- Compressor
- Cooling tower
- Damper
- Dehumidifier
- Duct
- Economizer
- Electrostatic precipitator
- Evaporative cooler
- Evaporator
- Exhaust hood
- Expansion tank
- Fan
- Fan coil unit
- Fan filter unit
- Fan heater
- Fire damper
- Fireplace
- Fireplace insert
- Freeze stat
- Flue
- Freon
- Fume hood
- Furnace
- Gas compressor
- Gas heater
- Gasline heater

**Measurement
and control**

- Air flow meter
- Aquastat
- BACnet
- Blower door
- Building automation
- Carbon dioxide sensor
- Clean air delivery rate (CADR)
- Control valve
- Gas detector
- Home energy monitor
- Humidistat
- HVAC control system
- Infrared thermometer
- Intelligent buildings
- LonWorks
- Minimum efficiency reporting value (MERV)
- Normal temperature and pressure (NTP)
- OpenTherm
- Programmable communicating thermostat
- Programmable thermostat
- Psychrometrics
- Room temperature
- Smart thermostat
- Standard temperature and pressure (STP)
- Thermographic camera
- Thermostat
- Thermostatic radiator valve

**Professions,
trades,
and services**

- Architectural acoustics
- Architectural engineering
- Architectural technologist
- Building services engineering
- Building information modeling (BIM)
- Deep energy retrofit
- Duct cleaning
- Duct leakage testing
- Environmental engineering
- Hydronic balancing
- Kitchen exhaust cleaning
- Mechanical engineering
- Mechanical, electrical, and plumbing
- Mold growth, assessment, and remediation
- Refrigerant reclamation
- Testing, adjusting, balancing

**Industry
organizations**

- AHRI
- AMCA
- ASHRAE
- ASTM International
- BRE
- BSRIA
- CIBSE
- Institute of Refrigeration
- IIR
- LEED
- SMACNA
- UMC

Health and safety

- Indoor air quality (IAQ)
- Passive smoking
- Sick building syndrome (SBS)
- Volatile organic compound (VOC)

See also

- ASHRAE Handbook
- Building science
- Fireproofing
- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Fire protection
- Template:Home automation
- Template:Solar energy

About Cook County

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Things To Do in Cook County

Photo

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Sand Ridge Nature Center

4.8 (96)

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River Trail Nature Center

4.6 (235)

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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

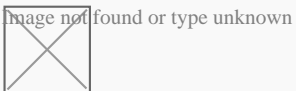
Driving Directions From Navy Pier to

<https://www.google.com/maps/dir/Navy+Pier/United+Structural+Systems+of+Illinois%2C+187.6050944,14z/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/United+Structural+Systems+of+Illinois%2C+187.8010774,14z/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+Systems+of+Illinois%2C+187.6490151,14z/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>

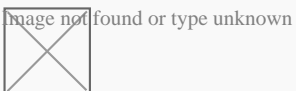
Reviews for



Jeffery James

(5)

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

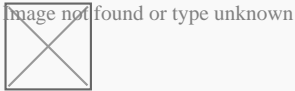


Sarah McNeily

(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

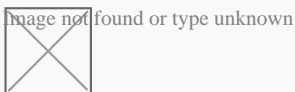
kept the job site meticulously clean. The crew was on time and friendly. I'd recommend them any day! Thanks to Jessie and crew.



Jim de Leon

(5)

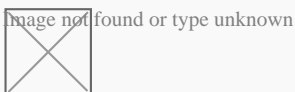
It was a pleasure to work with Rick and his crew. From the beginning, Rick listened to my concerns and what I wished to accomplish. Out of the 6 contractors that quoted the project, Rick seemed the MOST willing to accommodate my wishes. His pricing was definitely more than fair as well. I had 10 push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

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Company Website : <https://www.unitedstructuralsystems.com/>

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Foundation Repair Service

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