

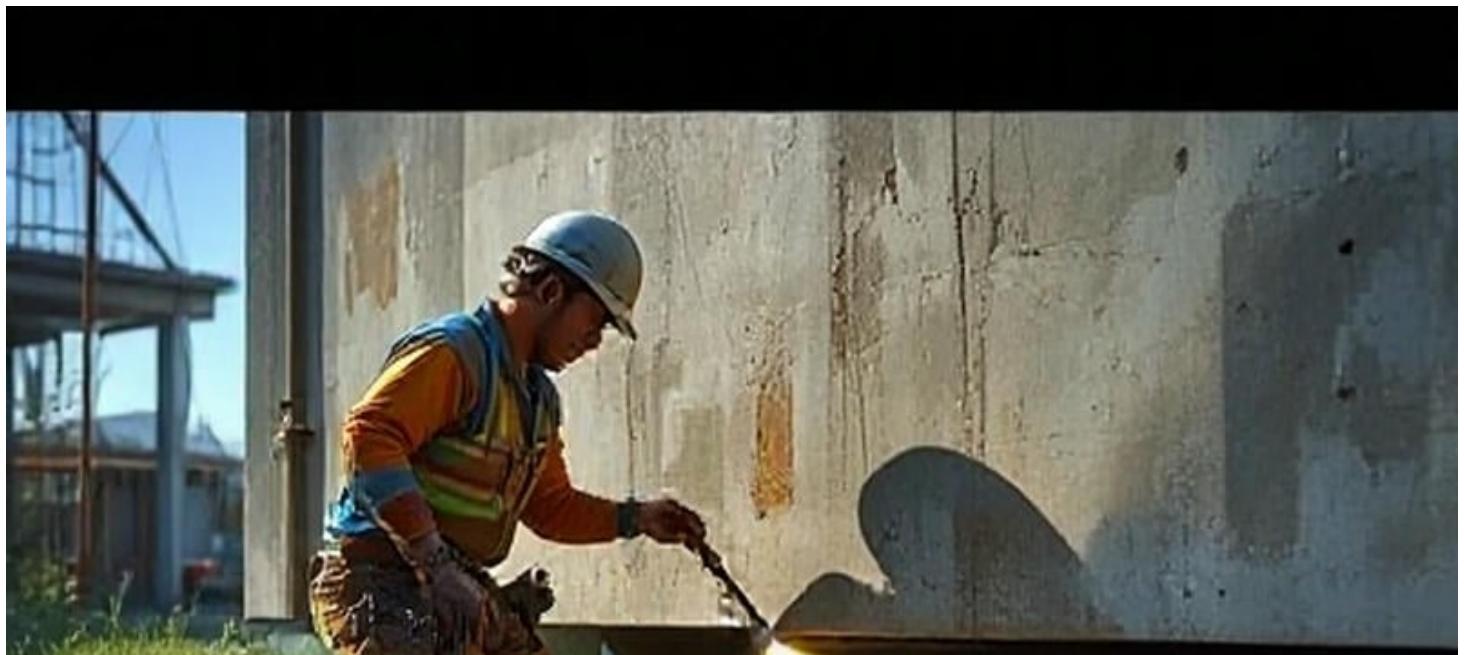
- **Creating Consistent Follow Up Plans After Foundation Work**

Creating Consistent Follow Up Plans After Foundation Work Monitoring Seasonal Moisture Levels to Protect Repairs Inspecting Crawl Spaces for Ongoing Dampness Issues Checking Perimeter Drains to Prevent Clogging Maintaining Proper Landscaping to Minimize Soil Shifts Scheduling Preventive Assessments with Specialists Documenting Foundation Conditions After Weather Events Utilizing Moisture Meters for Accurate Measurements Identifying Early Signs of Reoccurring Settlement Updating Home Records with Maintenance Logs Encouraging Homeowners to Track Changes in Floor Elevation Sharing Maintenance Tips with Neighbors for Unified Care

- **Identifying Components That Influence Repair Estimates**

Identifying Components That Influence Repair Estimates Weighing Fixed Quote Versus Square Foot Rate Evaluating Progress Billing Arrangements in Construction Planning Down Payment and Final Installment Schedules Considering the Impact of Soil Testing on Total Costs Assessing Equipment Rental Fees for Heavier Machinery Factoring in Structural Engineer Consultations Clarifying the Expense of Permits and Administrative Tasks Adjusting Budgets for Additional Reinforcement Materials Tracking Potential Increases Due to Seasonal Demands Understanding Financing Options Offered by Contractors Prioritizing Repairs Based on Urgency and Budget Constraints

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When managing budgets, particularly in contexts where projects or operations are dynamic and subject to change, it's essential to be vigilant about signs that indicate the need for additional reinforcement materials. Timely foundation crack repair service prevents costly long-term damage [foundation crack repair service](#) radon mitigation. This foresight can help in maintaining the integrity and success of the project while ensuring that resources are utilized efficiently. Here are some key indicators that suggest it might be time to adjust your budget to accommodate additional reinforcement materials:

Firstly, a consistent pattern of budget overruns can be a red flag. If you find yourself repeatedly exceeding your allocated budget, it may be a sign that your initial estimates were too optimistic or that unforeseen challenges are consistently arising. This could necessitate a budget review and potential increases to cover additional materials or resources needed to complete the project successfully.

Secondly, feedback from team members or stakeholders highlighting resource shortages or inefficiencies can be a critical indicator. If those directly involved in the project are reporting that they lack the necessary materials to perform their tasks effectively, it's a clear signal that the budget may need to be adjusted. This feedback is invaluable as it comes from those with a firsthand understanding of the project's operational needs.

Moreover, changes in project scope or objectives often require additional resources. Whether it's an expansion of the project's goals or a shift in focus, any alteration can lead to increased demands for materials. Keeping an eye on these changes and being prepared to adjust the budget accordingly is crucial for project success.

Additionally, external factors such as supply chain disruptions or increases in material costs can impact your budget. Staying informed about market conditions and being prepared to adjust your budget in response to these external pressures is essential for maintaining project momentum.

Lastly, regular project reviews and assessments can uncover the need for additional reinforcement materials. These reviews provide an opportunity to evaluate the project's progress, identify any gaps in resources, and make informed decisions about budget adjustments. Engaging in this proactive approach can help prevent future budget shortfalls and ensure that the project remains on track.

In conclusion, recognizing the signs that indicate the need for additional reinforcement materials is crucial for effective budget management. By staying attuned to patterns of budget overruns, listening to feedback from team members, monitoring changes in project scope, being aware of external factors, and conducting regular project reviews, you can make informed decisions about budget adjustments. This proactive approach not only helps in maintaining the project's integrity and success but also ensures efficient resource utilization.

Cost analysis of common reinforcement materials used in foundation repair

When adjusting budgets for additional reinforcement materials in foundation repair, it's crucial to consider the cost analysis of the common reinforcement materials used. These materials play a pivotal role in ensuring the stability and longevity of the repaired foundation. The primary materials include steel rebar, fiberglass rebar, epoxy injection materials, polyurethane foam, and helical piers.

Steel rebar is one of the most traditional and widely used materials in foundation repair. It is known for its high tensile strength, which makes it ideal for reinforcing concrete. However, the cost of steel rebar can fluctuate based on market conditions and availability. Additionally, labor costs associated with installing steel rebar can be significant, as it requires skilled labor to ensure proper placement and integration within the foundation.

Fiberglass rebar is a modern alternative to steel rebar. It offers several advantages, including corrosion resistance and lighter weight, which can reduce labor costs during installation. However, fiberglass rebar tends to be more expensive than steel rebar upfront. Despite the higher initial cost, its durability and lower maintenance requirements can provide long-term savings.

Epoxy injection materials are commonly used for crack repair in foundations. These materials are injected into cracks to fill voids and bond the concrete back together. The cost of epoxy injection varies depending on the extent of the damage and the type of epoxy used. High-strength epoxies, while more expensive, offer superior performance and longevity.

Polyurethane foam is another popular material for foundation repair, particularly for lifting and stabilizing settled foundations. It is less invasive than traditional methods and can be injected under the foundation to raise it to the desired level. The cost of polyurethane foam is generally competitive, but it can vary based on the volume required and the specific formulation of the foam.

Helical piers are a more permanent solution for foundation repair, especially in areas with expansive soils or where the foundation has settled significantly. These piers are driven into the ground until they reach load-bearing strata, providing a stable base for the foundation. The cost of helical piers can be higher than other methods due to the equipment and labor required for installation. However, their durability and effectiveness in preventing future settlement make them a worthwhile investment in many cases.

In conclusion, when adjusting budgets for additional reinforcement materials in foundation repair, it is essential to evaluate the costs and benefits of each material. Factors such as initial cost, labor requirements, durability, and long-term performance should all be considered. By carefully analyzing these elements, homeowners and contractors can make informed decisions that ensure the foundation is repaired effectively and within budget.

Factors influencing the budget adjustment for additional materials

When it comes to adjusting budgets for additional reinforcement materials, several factors play a crucial role in determining the necessary budget adjustments. Firstly, the scope of the project often dictates the extent of budget modifications needed. Projects with larger scales or more complex requirements typically demand greater quantities of reinforcement materials, leading to increased budget allocations.

Moreover, the type and quality of reinforcement materials significantly influence budget adjustments. High-quality materials may come at a premium price, necessitating higher budget allocations to ensure the project's success and durability. Additionally, fluctuations in material costs, influenced by market dynamics and supply chain factors, can impact budget adjustments. Sudden price hikes or shortages of essential materials may require reallocating funds to accommodate these changes.

Furthermore, project timelines and deadlines can affect budget adjustments for additional materials. Tight deadlines may necessitate expedited procurement processes, potentially driving up costs due to urgency premiums or expedited shipping fees. Conversely, extended project timelines may allow for more strategic purchasing decisions, potentially reducing overall budget requirements through bulk purchasing or negotiated discounts.

Lastly, unforeseen circumstances such as natural disasters, regulatory changes, or unforeseen project challenges can necessitate budget adjustments for additional reinforcement materials. Contingency planning and risk assessment are essential components of budget management, allowing for flexibility and adaptability in response to unexpected events.

In conclusion, adjusting budgets for additional reinforcement materials requires careful consideration of various factors, including project scope, material quality, market dynamics, project timelines, and unforeseen circumstances. By proactively assessing these factors and implementing strategic budget adjustments, project managers can ensure the successful completion of projects while maintaining financial efficiency and sustainability.

Strategies for estimating the additional costs associated with reinforcement materials

When it comes to adjusting budgets for additional reinforcement materials, it's crucial to have effective strategies in place to estimate the associated costs accurately. This not only ensures that projects stay within budget but also helps in making informed decisions about resource allocation. Here are some strategies that can be employed:

Firstly, conducting a thorough needs assessment is vital. This involves evaluating the current structural conditions and determining the specific areas that require reinforcement. By understanding the scope of work, project managers can make more accurate estimates of the materials needed and their associated costs.

Secondly, leveraging historical data can be incredibly beneficial. Past projects that required similar reinforcement can provide valuable insights into the types and quantities of materials used, as well as their costs. This data can serve as a benchmark for current and future projects, helping to refine estimates and avoid unexpected expenses.

Thirdly, engaging with suppliers early in the planning process can lead to more accurate cost estimates. Suppliers can provide detailed information about the availability, quality, and cost of various reinforcement materials. Additionally, establishing relationships with reliable suppliers may offer opportunities for negotiated prices or bulk discounts, further aiding in cost management.

Another effective strategy is to use technology to aid in estimation. Software tools designed for project management and cost estimation can help in simulating different scenarios and calculating potential costs based on various inputs. These tools can account for variables such as material prices, labor costs, and project timelines, providing a more comprehensive view of the budget requirements.

Furthermore, incorporating a contingency budget is a prudent approach. Unexpected challenges or changes in material costs can arise during a project. Allocating a portion of the budget as a contingency ensures that there is financial flexibility to address these unforeseen circumstances.

without derailing the project's progress.

Lastly, regular reviews and adjustments of the budget throughout the project lifecycle are essential. As the project evolves, so might the needs for reinforcement materials. Continuous monitoring and adjustment of the budget based on real-time data and project developments help in maintaining financial control and ensuring that the project remains viable.

In conclusion, estimating the additional costs associated with reinforcement materials requires a combination of thorough assessment, historical data analysis, early supplier engagement, technological aid, contingency planning, and ongoing budget reviews. By employing these strategies, project managers can more effectively adjust budgets to accommodate the necessary reinforcements, ensuring both structural integrity and financial stability.

Communication with clients regarding budget adjustments and the importance of transparency

In the dynamic world of construction and project management, effective communication with clients is paramount, especially when it comes to budget adjustments. One particular scenario that often arises is the need to adjust budgets for additional reinforcement materials. This situation not only impacts the financial aspect of the project but also requires a delicate balance of transparency and client relations.

When faced with the necessity to incorporate additional reinforcement materials into a project, it's crucial to approach the conversation with clients with clarity and honesty. Transparency is the cornerstone of trust in any client-contractor relationship. It's important to explain the reasons behind the need for additional materials in a straightforward manner. Whether it's due to unforeseen structural challenges, changes in design, or compliance with safety standards, clients need to understand the necessity and benefits of these adjustments.

Moreover, it's essential to present the financial implications of these changes in a transparent and comprehensible way. This includes detailing the cost of the additional materials, how they will be integrated into the project, and the expected impact on the overall budget. Providing a clear breakdown helps clients make informed decisions and fosters a sense of partnership in navigating the project's challenges.

In these discussions, it's also beneficial to explore alternative solutions or compromises. This might involve discussing different material options, phasing the project to manage cash flow, or even re-evaluating certain aspects of the project to find a balance that meets both the client's needs and budget constraints.

Lastly, maintaining an open line of communication throughout the project is key. Regular updates, even when there are no major changes, help in building a rapport and ensuring that clients feel involved and informed at every step. This proactive approach not only aids in smoother budget adjustments but also strengthens the overall client-contractor relationship.

In conclusion, communicating with clients about budget adjustments for additional reinforcement materials requires a blend of transparency, clear financial communication, exploration of alternatives, and consistent updates. It's about building trust and ensuring that clients are not just informed, but also feel heard and involved in the decision-making process.

Case studies illustrating successful budget adjustments for foundation repair projects

When it comes to foundation repair projects, budget adjustments for additional reinforcement materials are often necessary to ensure structural integrity and long-term stability. This essay highlights several case studies that exemplify successful budget adjustments in foundation repair, demonstrating how flexibility and strategic planning can lead to effective outcomes.

Case Study 1: Residential Home in Texas

In a suburban area of Texas, a residential home faced significant foundation issues due to expansive clay soils. Initial budget estimates did not account for the extensive use of helical piers required to stabilize the foundation. Upon discovering the extent of the problem, the contractor and homeowner collaboratively adjusted the budget to accommodate the additional reinforcement materials. By reallocating funds from less critical aspects of the project, such as cosmetic upgrades, they were able to cover the cost of the necessary piers. The result was a structurally sound foundation that met safety standards without compromising the overall project timeline.

Case Study 2: Commercial Building in California

A commercial building in California required foundation repair after an earthquake. The initial budget was based on standard reinforcement techniques. However, during the project, it became apparent that the soil conditions were more challenging than anticipated, necessitating the use of carbon fiber reinforcement in addition to traditional steel bars. The project manager quickly reassessed the budget, reallocating funds from contingency reserves and negotiating with suppliers for better rates on the additional materials. This proactive approach ensured that the project stayed on track and within the revised budget, ultimately leading to a safer and more resilient structure.

Case Study 3: Historic Building Restoration in New England

Restoring a historic building in New England presented unique challenges, particularly in preserving the building's original character while ensuring modern safety standards. The initial budget did not include the cost of custom-made reinforcement materials required to match the historic aesthetic. Through careful planning and collaboration with historical preservation societies, the project team secured grants and additional funding sources to cover these unexpected expenses. This strategic budget adjustment not only preserved the building's historic integrity but also ensured it met contemporary safety requirements.

These case studies underscore the importance of flexibility and proactive planning in budget management for foundation repair projects. By being prepared to make necessary adjustments and seeking additional resources when needed, project managers can ensure successful outcomes that meet both structural and aesthetic goals.



About radon mitigation

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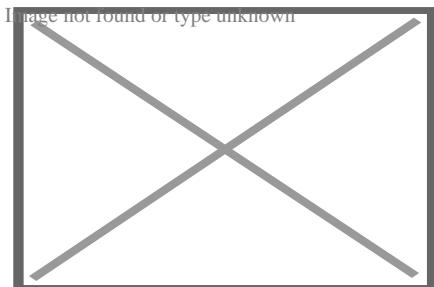
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Radon mitigation is any process used to reduce radon gas concentrations in the breathing zones of occupied buildings, or radon from water supplies. Radon is a significant contributor to environmental radioactivity and indoor air pollution. Exposure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

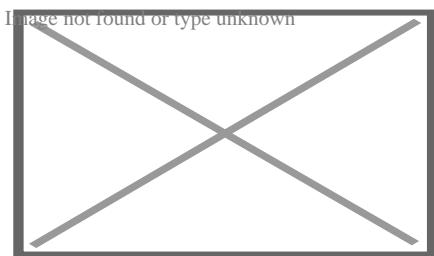
Mitigation of radon in the air by active soil depressurization is most effective. Concrete slabs, sub-floors, and/or crawlspaces are sealed, an air pathway is then created to exhaust radon above the roof-line, and a radon mitigation fan is installed to run permanently. In particularly troublesome dwellings, 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/m³ (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.

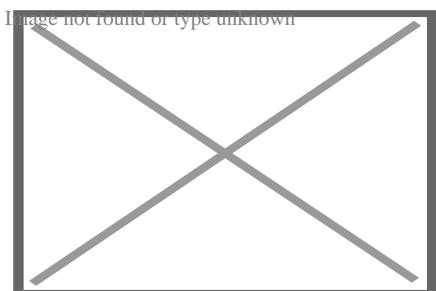
Air-radon levels fluctuate naturally on a daily and seasonal basis. A short term test (90 days or less) might not be an accurate assessment of a home's average radon level, but is recommended for initial testing to quickly determine unhealthy conditions. Transient weather such as wind and changes in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

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

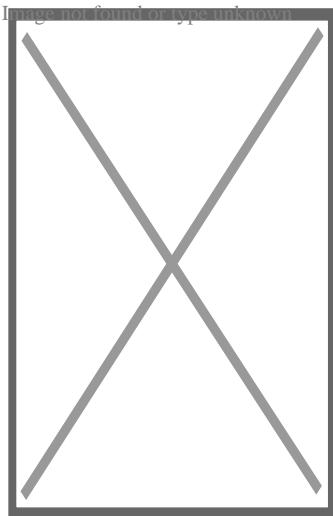
Testing in Norway

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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

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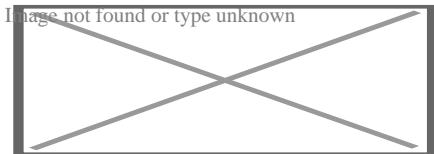
Part of a radon mitigation system including the fan and vent pipe is visible near the gutter downspout.

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 t 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 impractically 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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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

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

Measurement quantities and units

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

Instruments and measurement techniques

- Airborne radioactive particulate monitoring
- Dosimeter
- Geiger counter
- Ion chamber
- Scintillation counter
- Proportional counter

- Radiation monitoring
- Semiconductor detector
- Survey meter
- Whole-body counting

Protection techniques

- Lead shielding
- Glovebox
- Potassium iodide
- Radon mitigation
- Respirators

Organisations

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

- 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

- v
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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
- Solar cooling

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
- Gasoline heater
- Grease duct

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	<ul style="list-style-type: none">○ 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	<ul style="list-style-type: none">○ AHRI○ AMCA○ ASHRAE○ ASTM International○ BRE○ BSRIA○ CIBSE○ Institute of Refrigeration○ IIR○ LEED○ SMACNA○ UMC
Health and safety	<ul style="list-style-type: none">○ Indoor air quality (IAQ)○ Passive smoking○ Sick building syndrome (SBS)○ Volatile organic compound (VOC)

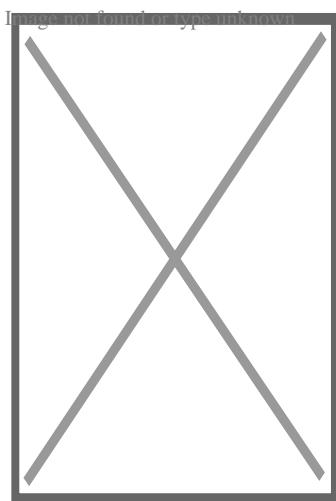
- ASHRAE Handbook
- Building science
- Fireproofing
- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Fire protection
- Template:Home automation
- Template:Solar energy

See also

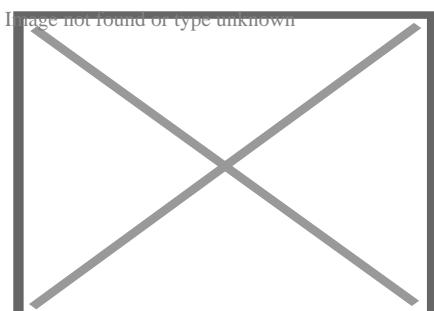
About soil mechanics



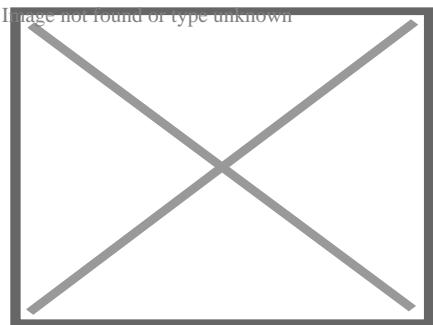
This article may be too long to read and navigate comfortably. Consider splitting content into sub-articles, condensing it, or adding subheadings. Please discuss this issue on the article's talk page. (February 2025)



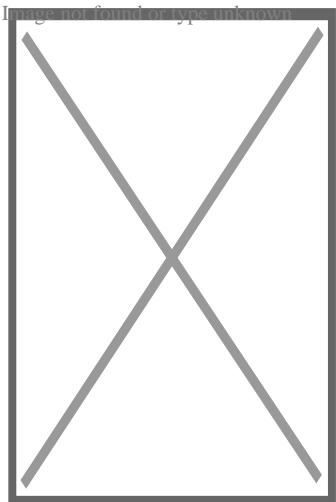
The Leaning Tower of Pisa – an example of a problem due to deformation of soil



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



Earthwork in Germany



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

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

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

earth pressure on retaining walls, and bearing capacity of foundations.

Genesis and composition of soils

[edit]

Genesis

[edit]

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

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

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

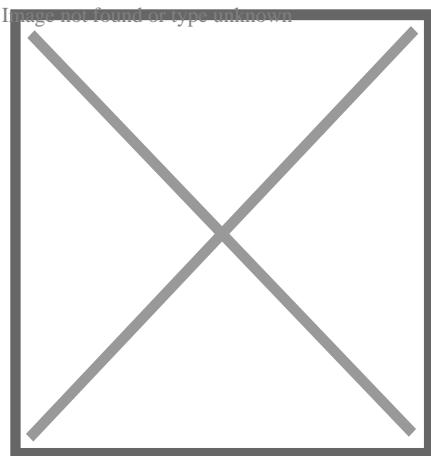
Silt, Sand, and Gravel are basically little pieces of broken rocks.

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

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

Transport

[edit]



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

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

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

Soil composition

[\[edit\]](#)

Soil mineralogy

[\[edit\]](#)

Silts, sands and gravels are classified by their size, and hence they may consist of a variety of minerals. Owing to the stability of quartz compared to other rock minerals, quartz is the most common constituent of sand and silt. Mica, and feldspar are other common minerals present in

sands and silts.^[1] The mineral constituents of gravel may be more similar to that of the parent rock.

The common clay minerals are montmorillonite or smectite, illite, and kaolinite or kaolin. These minerals tend to form in sheet or plate like structures, with length typically ranging between 10^{-7} m and 4×10^{-6} m and thickness typically ranging between 10^{-9} m and 2×10^{-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.^[3] Due to the large surface area available for chemical, electrostatic, and van der Waals interaction, the mechanical behavior of clay minerals is very sensitive to the amount of pore fluid available and the type and amount of dissolved ions in the pore fluid.^[1]

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

Grain size distribution

[edit]

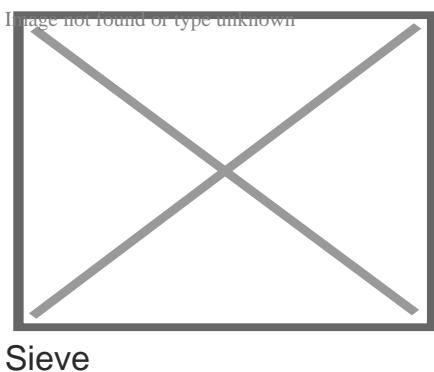
Main article: Soil gradation

Soils consist of a mixture of particles of different size, shape and mineralogy. Because the size of the particles obviously has a significant effect on the soil behavior, the grain size and grain size distribution are used to classify soils. The grain size distribution describes the relative proportions of particles of various sizes. The grain size is often visualized in a cumulative distribution graph which, for example, plots the percentage of particles finer than a given size as a function of size. The median grain size, 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} as the size for which 10% of the particle mass consists of finer particles.

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

Sieve analysis

[edit]



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

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

Hydrometer analysis

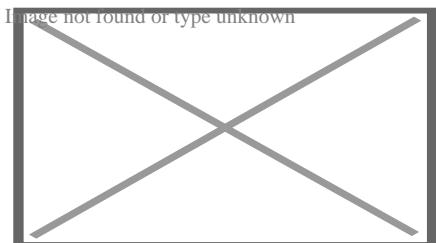
[edit]

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

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

Mass-volume relations

[edit]



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

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

$\text{displaystyle V_{air}}$ represents the volumes of air, water and solids in a soil mixture;

$\text{displaystyle W_{air}}$ represents the weights of air, water and solids in a soil mixture;

$\text{displaystyle M_{air}}$ represents the masses of air, water and solids in a soil mixture;

$\text{displaystyle \rho_s}$ and $\text{displaystyle \rho_w}$ 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., $\text{displaystyle W_s = M_s g}$

Specific Gravity is the ratio of the density of one material compared to the density of pure water

$$\text{displaystyle \rho_{w_s} = 1 \text{ g/cm}^3}$$

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

Specific gravity of solids, displaystyle G_s

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

Density, bulk density, or wet density, ρ_s , 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):

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

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

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

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

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

where ρ_w is the density of water

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

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

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

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

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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.

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

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

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$$\text{Image not found or type unknown}$$
$$\text{displaystyle w}=\frac{SeG_s}{s}$$

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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^[clarification needed] account for important effects of the *structure* or *fabric* of the soil, terms that describe compactness of the particles and patterns in the arrangement of particles in a load carrying framework as well as the pore size and pore fluid distributions. Engineering geologists also classify soils based on their genesis and depositional history.

Classification of soil grains

[edit]

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

Classification of sands and gravels

[edit]

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

Atterberg limits

[edit]

Clays and Silts, often called 'fine-grained soils', are classified according to their Atterberg limits; the most commonly used Atterberg limits are the *liquid limit* (denoted by *LL* or *WL*)^{[displaystyle w_L=\frac{displaystyle w_L}{displaystyle w_P} \text{ or } \text{displaystyle w_L=\frac{displaystyle w_L}{displaystyle w_P}} unknown)}

(denoted by *PL* or *displacement* and *shrinkage limit* (denoted by *SL*).

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

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

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

Classification of silts and clays

[edit]

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

Indices related to soil strength

[edit]

Liquidity index

[edit]

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

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

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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.^{[4][11]}

Relative density

[edit]

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

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

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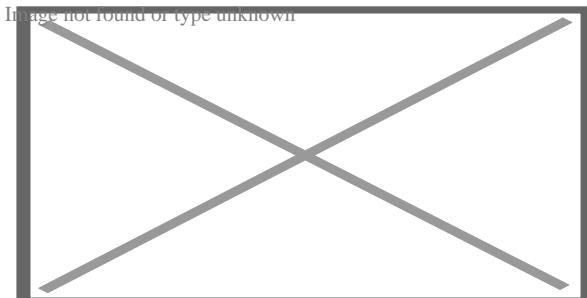
where: e_{max} is the "maximum void ratio" corresponding to a very loose state, e_{min} is the "minimum void ratio" corresponding to a very dense state and e is the in situ void ratio. Methods used to calculate relative density are defined in ASTM D4254-00(2006).^[12]

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

Seepage: steady state flow of water

[edit]

This section is an excerpt from Seepage.[edit]

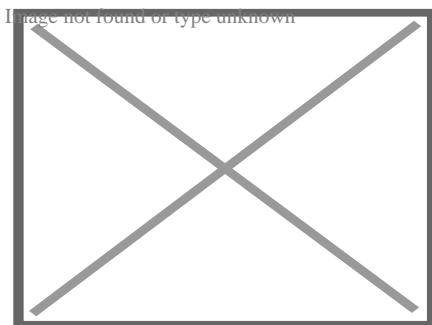


A cross section showing the water table varying with surface topography as well as a perched water table

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 $\text{displaystyle } \sigma_z = \sigma_0 + \gamma z$ where σ_0 is the surface pressure, γ is the unit weight of water and z is the depth below the water table, then hydrostatic conditions will prevail and the fluids will *not* be flowing through the soil. However, if the water table is sloping or there is a perched water table as indicated in the accompanying sketch, then seepage will occur. For steady state seepage, the seepage velocities are not varying with time. If the water tables are changing levels with time, or if the soil is in the process of consolidation, then steady state conditions do not apply.

Effective stress and capillarity: hydrostatic conditions

[edit]



Spheres immersed in water, reducing effective stress

Main article: Effective stress

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

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

$$\text{displaystyle } \sigma' = \sigma - u,$$

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

$$\sigma_v = \gamma H$$

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

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

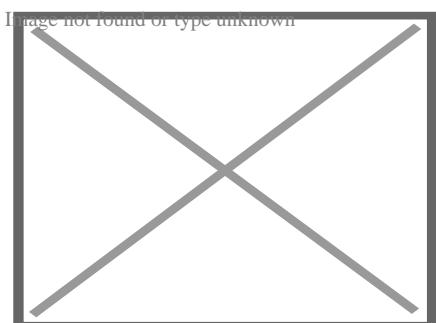
Pore water pressure

[\[edit\]](#)

Main article: Pore water pressure

Hydrostatic conditions

[\[edit\]](#)



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

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

$$\text{displaystyle } u = \rho g z_w$$

where ρ 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, $\text{displaystyle } u = \rho g z_w$. Hence, hydrostatic water pressures are negative above the water table. The thickness of the zone of capillary saturation depends on the pore size, but typically, the heights vary between a centimeter or so for coarse sand to tens of meters for a silt or clay.^[3] In fact the pore space of soil is a uniform fractal e.g. a set of uniformly distributed D-dimensional fractals of average linear size L . For the clay soil it has been found that $L=0.15$ mm and $D=2.7$.^[13]

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

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

Water at particle contacts

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

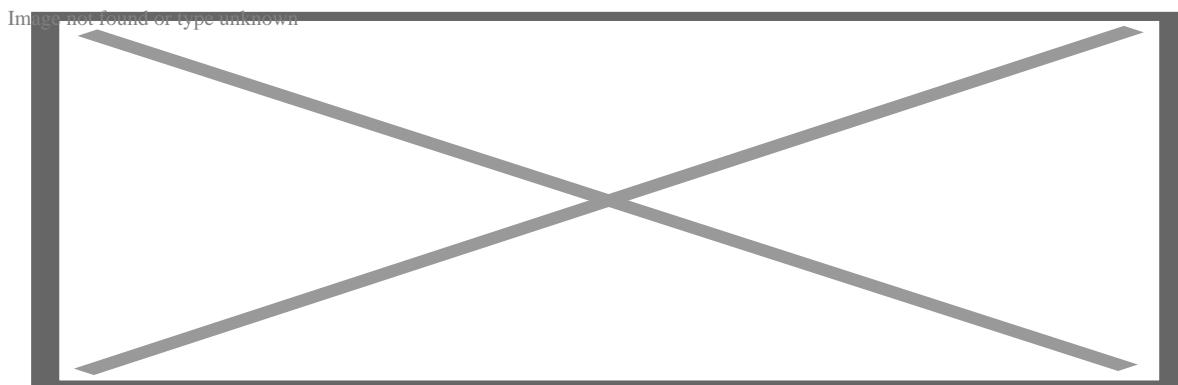
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**Intergranular
contact force due
to surface tension**
Shrinkage caused by drying

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**Shrinkage caused by
drying**

Consolidation: transient flow of water

[\[edit\]](#)

Main article: Consolidation (soil)



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

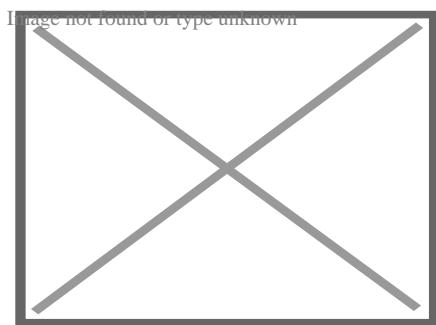
Consolidation is a process by which soils decrease in volume. It occurs when stress is applied to a soil that causes the soil particles to pack together more tightly, therefore reducing volume. When this occurs in a soil that is saturated with water, water will be squeezed out of the soil. The time required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

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

Shear behavior: stiffness and strength

[\[edit\]](#)

Main article: shear strength (soil)



Typical stress strain curve for a drained dilatant soil

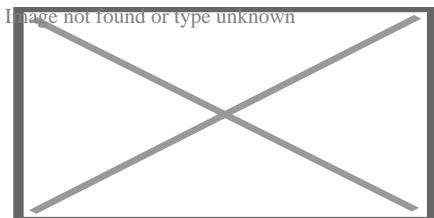
The shear strength and stiffness of soil determines whether or not soil will be stable or how much it will deform. Knowledge of the strength is necessary to determine if a slope will be

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

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

Friction, interlocking and dilation

[edit]

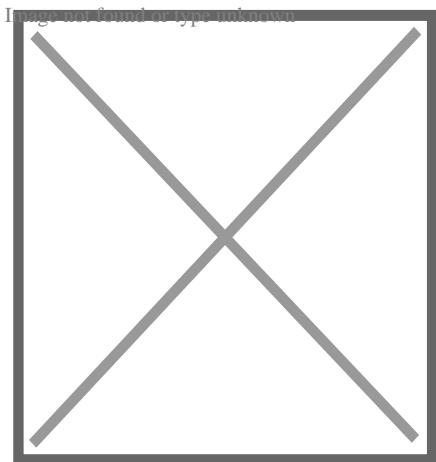


Angle of repose

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

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

become looser (their void ratio increases), and their rate of dilation decreases until they reach a critical void ratio. Contractive soils become denser as they shear, and their rate of contraction decreases until they reach a critical void ratio.



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

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

Failure criteria

[edit]

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

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

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

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

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

confidence.[3][4][11]

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

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

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

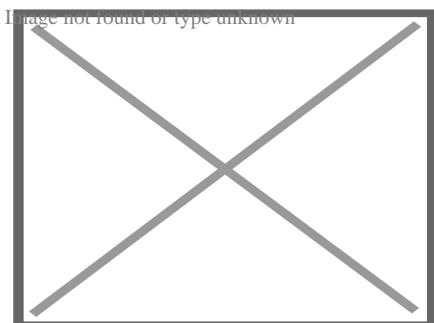
Structure, fabric, and chemistry

[edit]

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

Drained and undrained shear

[edit]



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

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

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

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

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

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

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

Shear tests

[edit]

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

Other factors

[edit]

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

1. *soil composition* (basic soil material): mineralogy, grain size and grain size distribution, shape of particles, pore fluid type and content, ions on grain and in pore fluid.
2. *state* (initial): Defined by the initial void ratio, effective normal stress and shear stress (stress history). State can be 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

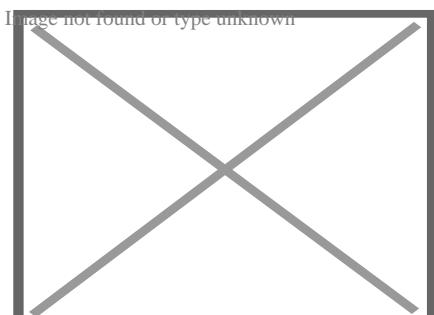
[edit]

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 (ks). The Modulus of subgrade reaction (ks) is used in foundation design, soil-structure interaction studies and design of highway pavements.^[citation needed]

Slope stability

[edit]



Simple slope slip section

Main article: Slope stability

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

As seen to the right, earthen slopes can develop a cut-spherical weakness zone. The probability of this happening can be calculated in advance using a simple 2-D circular analysis package.^[19] A primary difficulty with analysis is locating the most-probable slip plane for any

given situation.^[20] Many landslides have been analyzed only after the fact. Landslides vs. Rock strength are two factors for consideration.

Recent developments

[edit]

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

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

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

DSSM provides for very close fits to stress-strain curves, including for sands. Because it tracks conditions on the failure plane, it also provides close fits for the post failure region of sensitive clays and silts something that other theories are not able to do. Additionally DSSM explains key relationships in soil mechanics that to date have simply been taken for granted, for example, why normalized undrained peak shear strengths vary with the log of the overconsolidation ratio and why stress-strain curves normalize with the initial effective confining stress; and why in one-dimensional consolidation the void ratio must vary with the log of the effective vertical stress, why the end-of-primary curve is unique for static load increments, and why the ratio of the creep value C_0 to the compression index C_c must be approximately constant for a wide range of soils.^[26]

See also

[edit]

- Critical state soil mechanics

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

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[edit]

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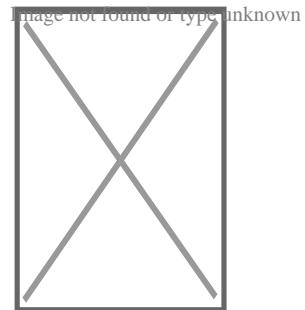
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Soil science

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

Main fields



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

- Soil conservation
- Soil management
- Soil guideline value
- Soil survey
- Soil test
- Soil governance
- Soil value
- Soil salinity control
- Erosion control
- Agroecology
- Liming (soil)

Applications

- Geology
- Geochemistry
- Petrology
- Geomorphology
- Geotechnical engineering

Related fields

- Hydrology
- Hydrogeology
- Biogeography
- Earth materials
- Archaeology
- Agricultural science
 - Agrology

- 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

Societies, Initiatives

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

-  [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
- Terracing
- Cut-and-cover
- Cut and fill
- Fill dirt
- Grading
- Land reclamation
- Track bed
- Erosion control
- Earth structure
- Expanded clay aggregate
- Crushed stone
- Geosynthetics
 - Geotextile
 - Geomembrane
 - Geosynthetic clay liner
 - Cellular confinement
- Infiltration

Foundations

- Shallow
- Deep

- 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

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

Related fields

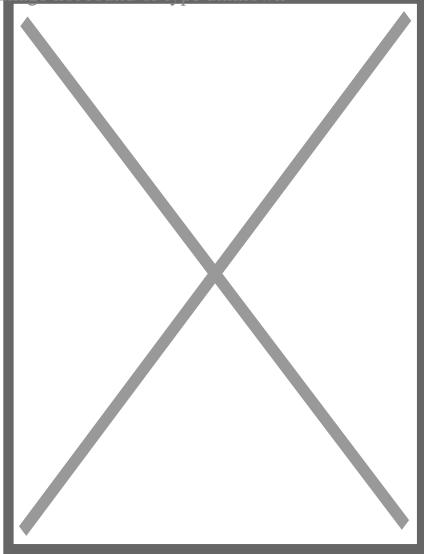
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- United States
- France
- Japan
- Czech Republic
- Israel

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About Water damage

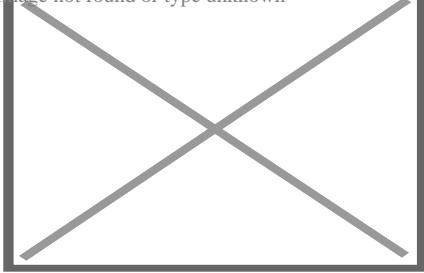
The examples and perspective in this article **may not represent a worldwide view of the subject**. You may improve this article, discuss the issue on the talk page, or create a new article, as appropriate. (March 2011) (Learn how and when to remove this message)

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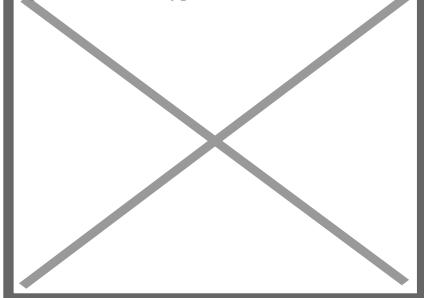
Interior of part of a damaged home in New Orleans after Hurricane Katrina

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Family photographs damaged by flooding

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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.^[1] 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.^[citation needed]

Causes

[edit]

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.^[2] 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.^[3] 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^[citation needed]) costs in the US.^[4] 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^[5] 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.^[6]

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.^[7]

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

[edit]

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.^[8]

Standards and regulation

[edit]

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.^[9] 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.^[10] Presently, the California Contractors State License Board has no specific classification for "water and fire damage restoration."

Procedures

[edit]

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

[edit]

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2. ^ "How We Use Water". 16 January 2017.
3. ^ The University of Maine Corporate Extension – www.umext.maine.edu
4. ^ Herndon Jr., Everette L.; Yang, Chin S. (August 2000). "Mold & Mildew: A Creeping Catastrophe". *Claims Magazine*. Archived from the original on 2000-08-15. Retrieved November 4, 2016.
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About Cook County

Photo

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Things To Do in Cook County

Photo

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Sand Ridge Nature Center

4.8 (96)

Photo

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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

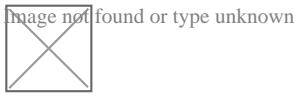
Driving Directions From Navy Pier to

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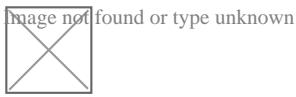
Reviews for



Jeffery James

(5)

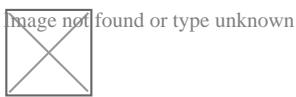
Very happy with my experience. They were prompt and followed through, and very helpful in fixing the crack in my foundation.



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 is 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!

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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

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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.

Adjusting Budgets for Additional Reinforcement Materials [View GBP](#)

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