OSHAcademy™
Occupational Safety & Health Training

Trench and Excavation Safety

This course helps to address requirements of the Excavation and Trenching Standard set forth by OSHA. Catered to equipment operators, workers and all others associated with trenching and excavating, each student will learn how to recognize hazardous conditions that could result in injury or a fatality. Soil composition is discussed in moderate detail to provide a general overview of the various properties associated with different types of soil and how to predict their behavior in varying conditions. Some of the most common types of soil conditions that lead to trench and excavation failure are also discussed. You will learn the basic trenching operations that help make a trench safe for workers, methods for protecting employees against cave-ins, and other safe work practices for employees.

About the Cover

Airmen from the 455th Expeditionary Civil Engineer Squadron peer into a trench that marks the future location of a water line. The Airmen reviewed trench safety procedures with the help of the 455th Air Expeditionary Wing Safety office and contracted construction workers and engineers. These types of projects present numerous dangers for workers to be aware of; Airmen were able to learn about the hazards and how to safeguard against them. (U.S. Air Force photo by Capt. Keenan Kunst)

OSHAcademy Course 802 Study Guide

Excavation Safety

Contact OSHAcademy to arrange for use as a training document.

This study guide is designed to be reviewed off-line as a tool for preparation to successfully complete OSHAcademy Course 802.

Read each module, answer the quiz questions, and submit the quiz questions online through the course webpage. You can print the post-quiz response screen which will contain the correct answers to the questions.

The final exam will consist of questions developed from the course content and module quizzes.

We hope you enjoy the course and if you have any questions, feel free to email or call:

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Disclaimer

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Course Introduction

The Occupational Safety and Health Administration issued its first Excavation and Trenching Standard in 1971 to protect workers from excavation hazards. Since then, OSHA has amended the standard several times to increase worker protection and to reduce the frequency and severity of excavation accidents and injuries. Despite these efforts, excavation related accidents resulting in injuries and fatalities continue to occur.

This course helps to address requirements of the standard, as well as provide information for equipment operators, workers and all others associated with trenching and excavating to help recognize hazardous conditions that could result in injury or a fatality. This guide discusses soil composition in moderate detail to provide a general overview of the various properties associated with different types of soil. A general understanding of the properties of soil is the first step in predicting the behavior of soils in varying conditions. Some of the most common types of soil conditions that lead to trench and excavation failure are also discussed.

Proper trenching operations are necessary to protect the workers from soil collapse. The basic trenching operations that help make a trench safe for workers are described and illustrated. The methods of shoring installation are also discussed briefly. This course is not intended to be used as a step-by-step guideline in the excavation process.

This course highlights the requirements in the updated standard for excavation and trenching operations, provides methods for protecting employees against cave-ins, and describes safe work practices for employees. A necessary first step in planning the approach to any trenching or other excavation project is to understand what could go wrong. This understanding can help avoid many of the problems associated with excavation.

This course is also not intended to be a guideline for compliance with all pertinent OSHA regulations, but rather an overview of safe practices in trenching operations. Though the course is not intended to be inconsistent with OSHA standards, if an area is considered by the reader to be inconsistent, the OSHA standard should be followed.

Special thanks to the North Carolina Department of Labor for the content of this course. Other sources include:

- U.S. Department of Labor, Occupational Safety and Health Administration (OSHA)
- Oregon Department of Occupational Safety and Health (OR-OSHA)
- Ohio Bureau of Workers' Compensation

- Texas Department of Insurance

Module 1: Scope and Application of OSHA Standard

OSHA revised the excavations standard in 1989, with focus on the existing standard to simplify many of the existing provisions, add and clarify definitions, eliminate duplicate provisions and ambiguous language, and give employers added flexibility in providing protection for employees.

In addition, the standard provides several new appendices. Appendix A to 1926.652 provides a consistent method of soil classification. Appendix B to 1926.652 provides sloping and benching requirements. Other appendixes (appendices C-F) provide pictorial examples of shoring and shielding devices, timber tables, hydraulic shoring tables, and selection charts that provide a graphic summary of the requirements contained in the standard.

For more information on the details of proper installation, please refer to the OSHA standard on excavation (29 CFR 1926 Subpart P, which includes 650-652 and appendices A-F).

Applying OSHA Standard

The OSHA standard applies to all open excavations made in the earth's surface, which includes trenches. According to the OSHA construction safety and health standards:

- a **trench** is referred to as a narrow excavation made below the surface of the ground in which the depth is greater than the width (the width not exceeding 15 feet or 4.5 meters).
- an **excavation** is any man-made cut, cavity, trench or depression in the earth's surface formed by earth removal. This can include excavations for anything, from cellars to highways.

The standard does not apply to house foundation/basement excavations (including those that become trenches by definition when formwork, foundations or walls are constructed) when all of the following conditions are present:

- The house foundation/basement excavation is less than 7 1/2 feet (2.5 meters) deep or is benched for at least 2 feet (0.61 meters) horizontally for every 5 feet (1.52 meters) or less of vertical height.
- The minimum horizontal width (excavation face to formwork/wall) at the bottom of the excavation is as wide as practicable but not less than 2 feet (0.61 meters).

- There is no water, surface tension cracks or other environmental conditions present that reduce the stability of the excavation.

- There is no heavy equipment operating in the vicinity that causes vibration to the excavation while employees are in the excavation.

- All soil, equipment and material surcharge loads are no closer in distance to the top edge of the excavation than the excavation is deep; however, when front end loaders are used to dig the excavations, the soil surcharge load must be placed as far back from the edge of the excavation as possible, but <u>never</u> closer than 2 feet (0.61 meters).

- Work crews in the excavation are the minimum number needed to perform the work.

- The work has been planned and is carried out in a manner to minimize the time employees are in the excavation.

The standard provides several options for designing trench protection measures. Under certain conditions, the design of the trench protection measures must be prepared by a registered professional engineer.

Competent Person and the Standard

Proper selection and installation of trench protection measures are very important. To comply with the standard, the employer must have a competent person:

> *"one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them."*

This competent person has critical inspection responsibilities regarding excavations. This person must inspect every excavation and protective system under his or her care daily, including areas near any excavation. Additional inspections must be conducted before starting work and as needed through a shift, for example, when any hazard-increasing occurrence (such as a rainstorm) takes place. When the competent person finds any evidence of a situation that could result in a cave-in, protective system failure or any other hazardous condition, employees are to be immediately removed from the danger area until the problem is fixed.

The items below discuss more trenching and excavation activities where a competent person is necessary:

- Protective Systems or Equipment
    - Monitoring water removal equipment and operations
    - Inspecting excavations subject to runoff from heavy rains
    - Determining cave-in potential to assess the need for shoring or other protective systems
    - Classifying soil and rock deposits
    - Determining the appropriate slope of an excavation to prevent collapse
- Inspecting Trench and Protective Systems
    - Authorizing immediate removal of employees from an area where there is evidence of a possible cave-in, a failure of protective systems, and where hazardous atmospheres exist.
- Unsafe Access/Egress
    - Designing structural ramps used only by employees as a means of access or egress. Structural ramps used for access or egress of equipment must be designed by a competent person qualified in structural design.

Written Policies

Many companies have established a written policy that outlines specific safe trenching practices in detail. Such a policy should ensure adequate support for the trench and frequent inspections of the excavation site to detect any change in the soil conditions.

Field and office personnel should become familiar with the company policies and guidelines outlined in the company safety program. The program may be put into writing to communicate the company's position regarding jobsite safety. An example of a company safety and health program in action is a written policy that ensures all employees in all excavations will be protected from cave-ins. When this type of policy is enforced, all employees understand their responsibilities and that helps to avoid unsafe practices.

Scenario

On January 28, 2003, two Hispanic construction laborers [15 and 16-year-old brothers] died when the trench they were working in experienced a cave-in. The victims were members of a crew installing conduit in an eight-foot-deep by two-foot-wide trench.

When work started, the jobsite foreman instructed the crew leader to operate a backhoe to dig the trench. The foreman then left the site to check on another job. After approximately an hour, the crew leader grounded the bucket, turned the machine off and walked to the company trailer to check blueprints.

As he was looking at the blueprints, he heard loud voices outside the trailer from the direction of the ditch. As he exited the trailer, he was informed by one of the workers that the trench had collapsed and that the two employees had been covered up.

The emergency medical squad (EMS) was summoned and responded within minutes.

Coworkers had uncovered the victims and removed them from the trench as the rescue squad arrived. The victims could not be revived and the county coroner was summoned to the scene where he pronounced the victims' dead.

NIOSH investigators concluded that, to help prevent similar occurrences, employers should:

- Ensure that a competent person conducts daily inspection of excavations, adjacent areas, and protective systems and takes appropriate measures necessary to protect workers.
- Ensure that workers are protected from cave-ins by an adequate protective system.
- Develop, implement, and enforce a comprehensive written safety program for all workers which includes training in hazard recognition and the avoidance of unsafe conditions.

- Ensure that workers who are part of a multilingual workforce comprehend instructions in safe work procedures for the tasks to which they are assigned.

- Ensure that only qualified rescue personnel who have assumed responsibility for rescue operations and site safety should attempt rescue operations.

Module 1 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **An excavation is any man-made cut, cavity, trench or depression in the earth's surface formed by earth removal.**

    a. True
    b. False

2. **When does the OSHA standard <u>NOT</u> apply to house foundation/basement excavations?**

    a. If no water, surface tension cracks or other environmental conditions are present
    b. There is equipment present at the site
    c. Work crews in the excavation are the minimum number needed to perform the work
    d. Both A and C are correct

3. **All the following are requirements for a "competent person," <u>except</u> ________.**

    a. inspecting every excavation daily
    b. removing employees if a hazardous condition appears
    c. inspecting areas **near** any excavation
    d. firing employees for not complying with safety rules

4. **According to the OSHA Construction Safety and Health Standards, which choice is a characteristic of a trench?**

    a. Narrow excavation
    b. The depth is greater than the width
    c. The width should not exceed 10 feet
    d. Both A and B are correct
    e. All the above

5. **When a competent person finds any evidence of a situation that could result in a cave-in the competent person should __________.**

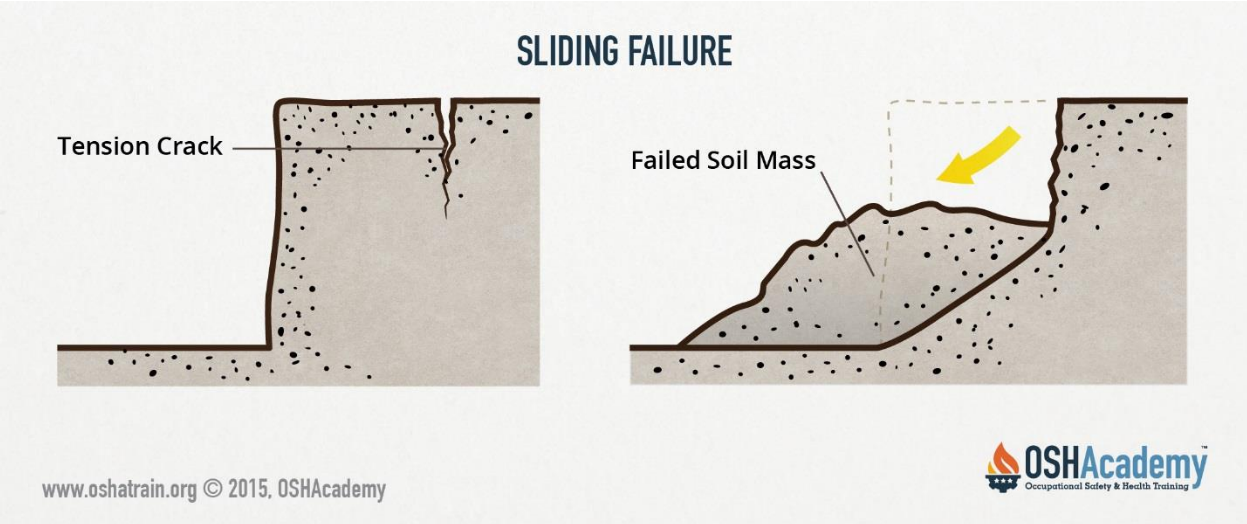
    a. immediately remove employees from the danger area
    b. increase the number of employees to shore up the trench
    c. call an engineer to review the danger area before removing employees
    d. All the above

Module 2: Common Soil Problems

The terms soil and earth are commonly referred to in the excavation process to describe the naturally occurring materials uncovered on a project. Soil conditions vary from one site to the next. Soil may be loose or partially cemented, organic or inorganic. However, most soils can be referred to as a mixture or an accumulation of mineral grains that are not cemented together. An exception is hard rock, which remains firm after exposure to the elements.

Soil failure is defined as the collapse of part or all of an excavation wall. The most common soil failure is typically described as an unexpected settlement, or cave-in, of an excavation. Soil sliding is the most common factor leading to soil failure.

Proper planning and supervision can avoid the unsafe working conditions caused by soil sliding. Unless such safety precautions have been implemented, sliding soil failure can occur in all types of excavations (including sloped trenches and excavations with braced trench boxes).

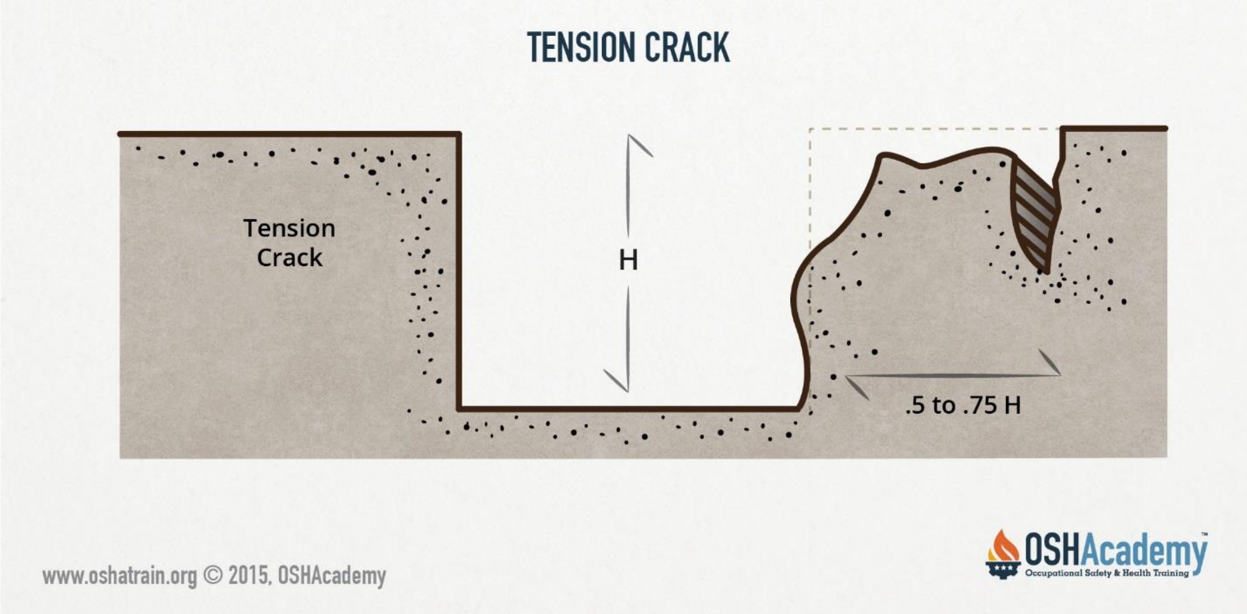


Soil Mechanics

A number of stresses and deformations can occur in an open cut or trench. For example, increases or decreases in moisture content can adversely affect the stability of a trench or excavation. The following diagrams show some of the more frequently identified causes of trench failure.

Tension Cracks

Tension cracks usually form at a horizontal distance of one-half to three-quarters times the depth of the trench, measured from the top of the vertical face of the trench.

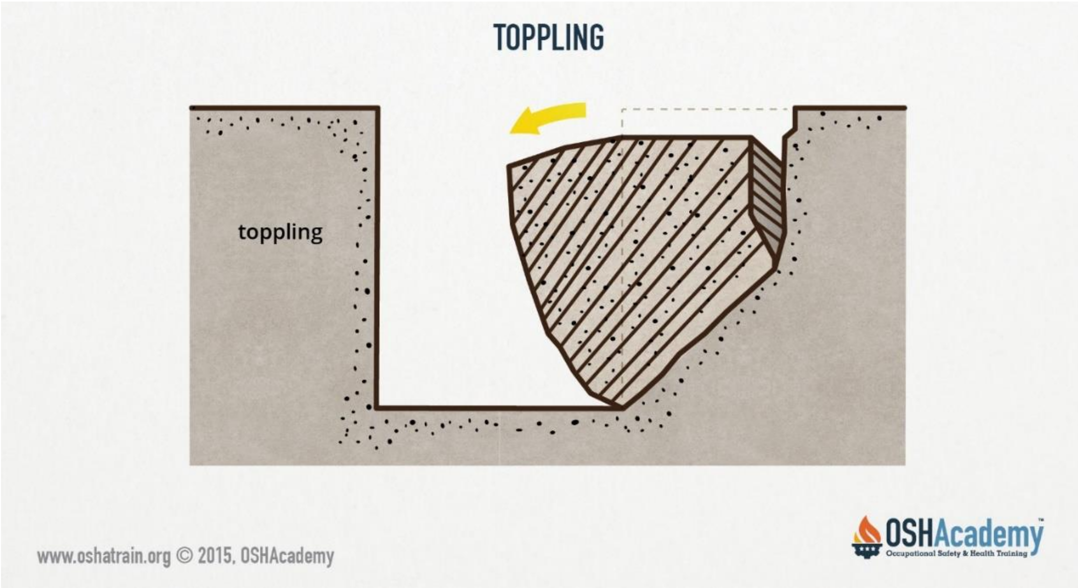


Sliding or Sluffing

This may occur as a result of tension cracks.

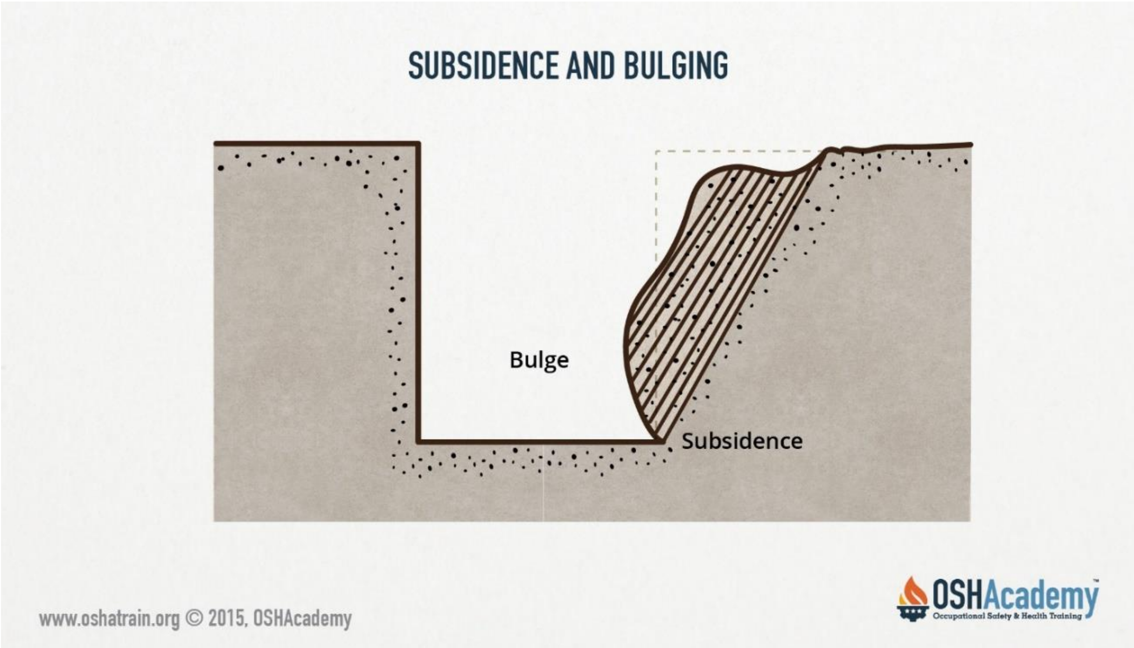
Toppling

In addition to sliding, tension cracks can cause toppling. Toppling occurs when the trench's vertical face shears along the tension crack line and topples into the excavation.



Subsidence and Bulging

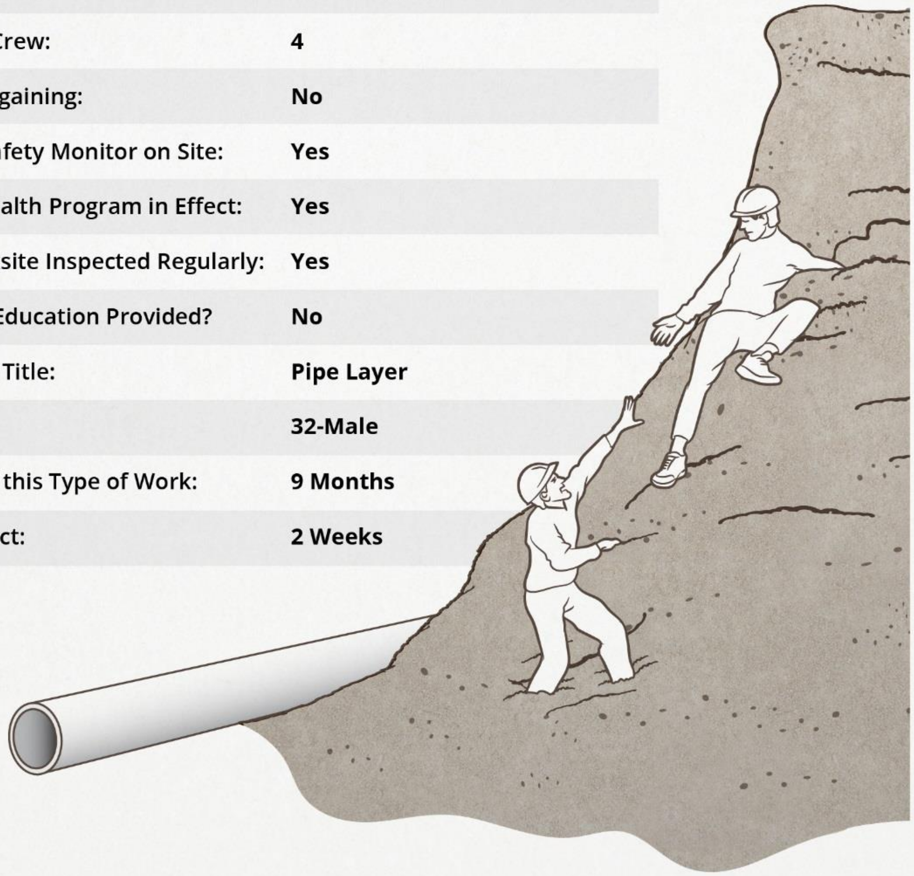
An unsupported excavation can create an unbalanced stress in the soil, which, in turn, causes subsidence at the surface and bulging of the vertical face of the trench. If uncorrected, this condition can cause face failure and entrapment of workers in the trench.



Fatal Facts

INSPECTION CASE STUDY

Accident Type:	**Cave-in**
Weather Conditions:	**Cloudy and Dry**
Type of Operation:	**Trenching and Excavation**
Size of Work Crew:	**4**
Collective Bargaining:	**No**
Competent Safety Monitor on Site:	**Yes**
Safety and Health Program in Effect:	**Yes**
Was the Worksite Inspected Regularly:	**Yes**
Training and Education Provided?	**No**
Employee Job Title:	**Pipe Layer**
Age & Sex:	**32-Male**
Experience at this Type of Work:	**9 Months**
Time on Project:	**2 Weeks**



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Brief Description of Accident

In the above "fatal facts," employees were laying sewer pipe in a trench 15 feet deep. The sides of the trench, 4 feet wide at the bottom and 15 feet wide at the top, were not shored or protected to prevent a cave-in. Soil in the lower portion of the trench was mostly sand and gravel and the upper portion was clay and loam. The trench was not protected from vibration caused by heavy vehicle traffic on the road nearby. To leave the trench, employees had to exit by climbing over the backfill. As they attempted to leave the trench, there was a small cave-in covering one employee to his ankles. When the other employee went to his co-worker's aid another cave-in occurred covering him to his waist. The first employee died of a rupture of the right ventricle of his heart at the scene of the cave-in. The other employee suffered a hip injury.

Inspection Results

Following an investigation, citations were issued alleging three willful, four serious and two non-serious violations of construction standards. If the trench was shored to prevent slides or cave-ins and had employees been trained to recognize and avoid unsafe conditions, the accident could have been prevented.

Accident Prevention Recommendations

1. Employers must instruct employees on how to recognize and avoid hazardous conditions and on regulations applicable to the work environment (29 CFR 1926.21(b)(2)).

2. Excavated and other materials must be effectively stored and retained at least two feet from the edge of the excavation (29 CFR 1926.651(i)(1)).

3. If in unstable or soft material, (5 feet or more in depth), the employer must ensure that they walls or sides of trenches be shored, sheeted, braced, sloped or protected in some manner in order to prevent cave-ins and protect employees required to work within them. (29 CFR 1926.652(b)).

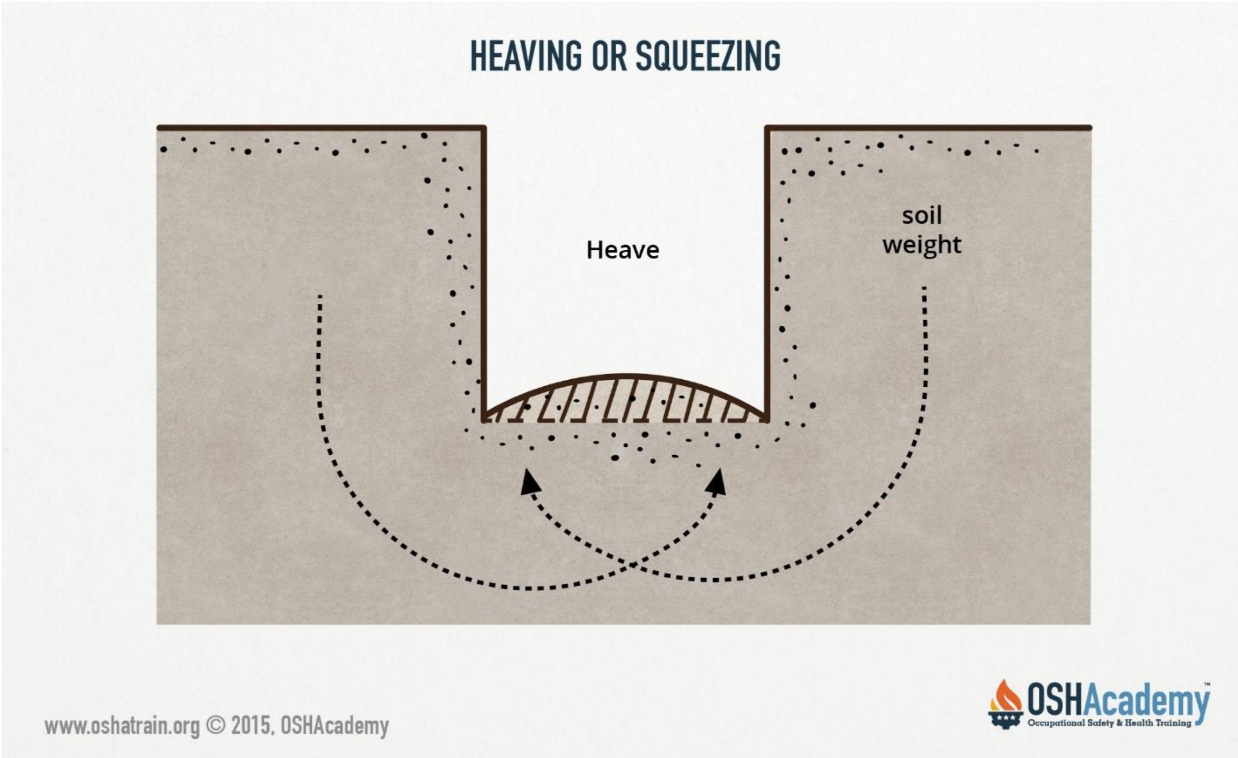
4. When excavations are subjected to vibrations from highway traffic, additional precautions must be taken to prevent cave-ins (29 CFR 1926.652 (e)).

5. Ladders must be provided as a means of exit when employees are required to be in trenches 4 or more feet deep (29 CFR 1926.652(h)).

Source: OSHA

Note: The case described above was selected as being representative of fatalities caused by improper work practices. No special emphasis or priority is implied nor is the case necessarily a recent occurrence. The legal aspects of the incident have been resolved, and the case is now closed.

Let’s now get back to the soil mechanics….


HEAVING OR SQUEEZING
Heave
soil
weight
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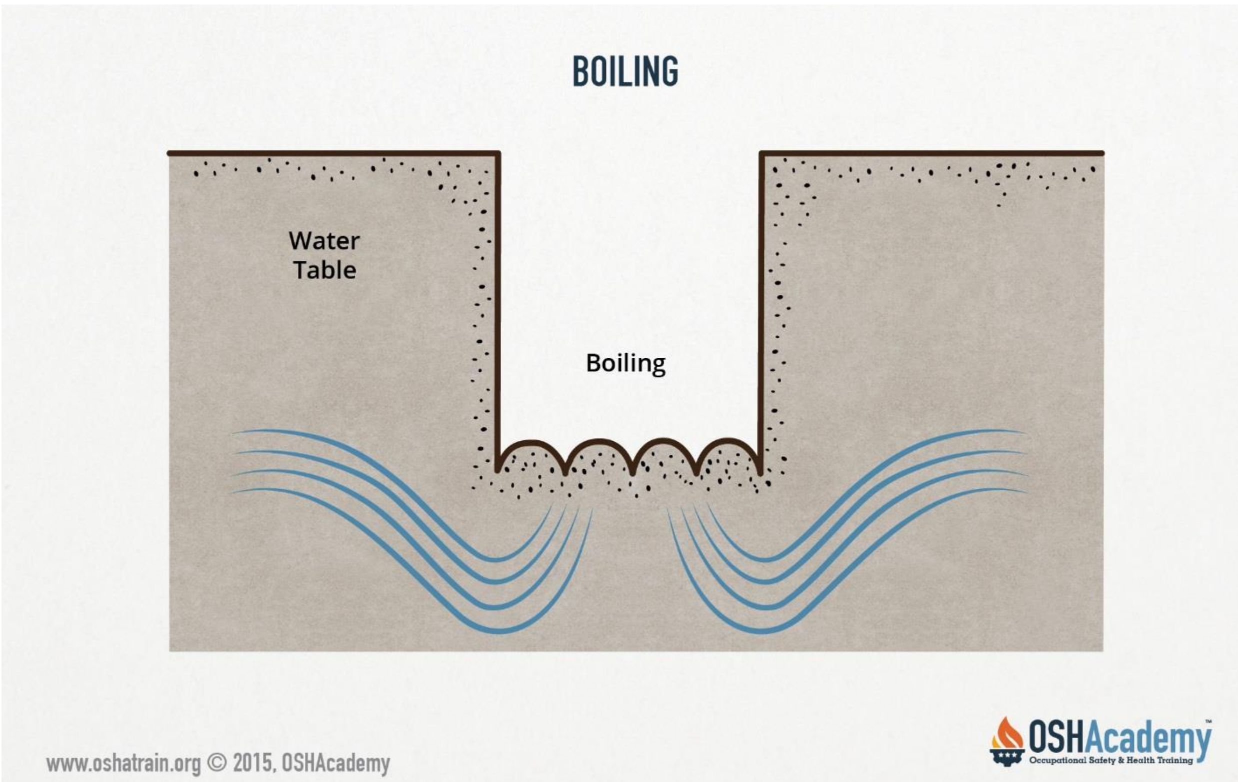
Heaving or Squeezing

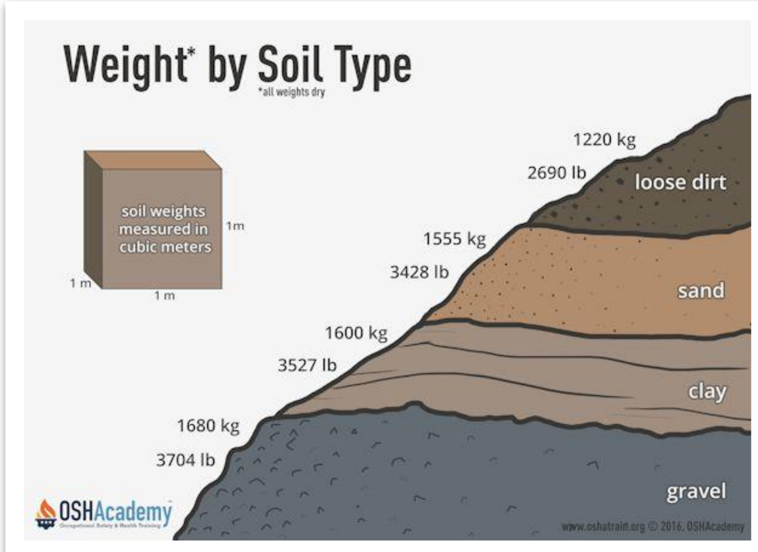
Bottom heaving or squeezing is caused by the downward pressure created by the weight of adjoining soil. This pressure causes a bulge in the bottom of the cut, as illustrated below. Heaving and squeezing can occur even when shoring or shielding has been properly installed.



Boiling

Boiling is evidenced by an upward water flow into the bottom of the cut. A high water table is one of the causes of boiling. Boiling produces a “quick” condition in the bottom of the cut and can occur even when shoring or trench boxes are used.

Unit Weight of Soils



This refers to the weight of one unit of a particular soil. The weight of soil varies with type and moisture content. One cubic foot of soil can weigh from 110 pounds to 140 pounds or more, and one cubic meter (35.3 cubic feet) of soil can weigh more than 3,000 pounds.

A safe slope can be defined as the maximum angle of the edge wall or bank of an excavation at which sliding will not occur. The unique mixtures of the different types of soil (sand, clay, silt and rock) necessitate different safe slopes from one excavation site to the next.

There are other complicating factors that can result in sliding soil failures. During an excavation, visibly different layers of soil may be uncovered. Each of those layers may call for different safe slopes. It is essential to plan your excavation around the most gradual (rather than steepest) safe slope for all the different soil types and layers encountered during the excavation.

Another complicating factor is that soil composition mixtures may vary significantly from one area of the project to another. During an excavation, as the soil composition changes, the safe slope for trench wall excavation also changes. Thus, across an excavation site, the slope of the bank may need to be different to provide a safe working environment.

Sliding Problems

Sliding and other modes of failure can also occur in soils that are not densely compacted. For example, a trench that is made close to a previously dug trench is very unstable. If non-compacted soil is discovered, the normal safe slope for dense soil will not be enough to prevent sliding. Bracing or further sloping may be necessary.

If cracks are observed in rocky types of soil, sliding has already occurred. These cracks should signal that a more gradual slope for excavation is needed because the rocky soil is very susceptible to slides and other types of failure.

Excavations that have been stable for long periods are also subject to sliding types of failure. After prolonged exposure to the elements, the moisture content in the soil may increase. This increase in moisture may be due to various causes, such as rainfall or a broken water line. The extra soil moisture tends to speed up sliding soil failures.

Determining the correct safe slope can be quite difficult for certain types of soil. The OSHA standard has developed a simple method of determining safe excavation bank slopes for different soil types. This method will be discussed in more detail in a later section of this document.

Soil failure can occur for any number of reasons. Factors that increase the chances of soil failure are:

1. excessive vibration
2. surface encumbrances
3. weather conditions

Cave-Ins and Protective Support Systems

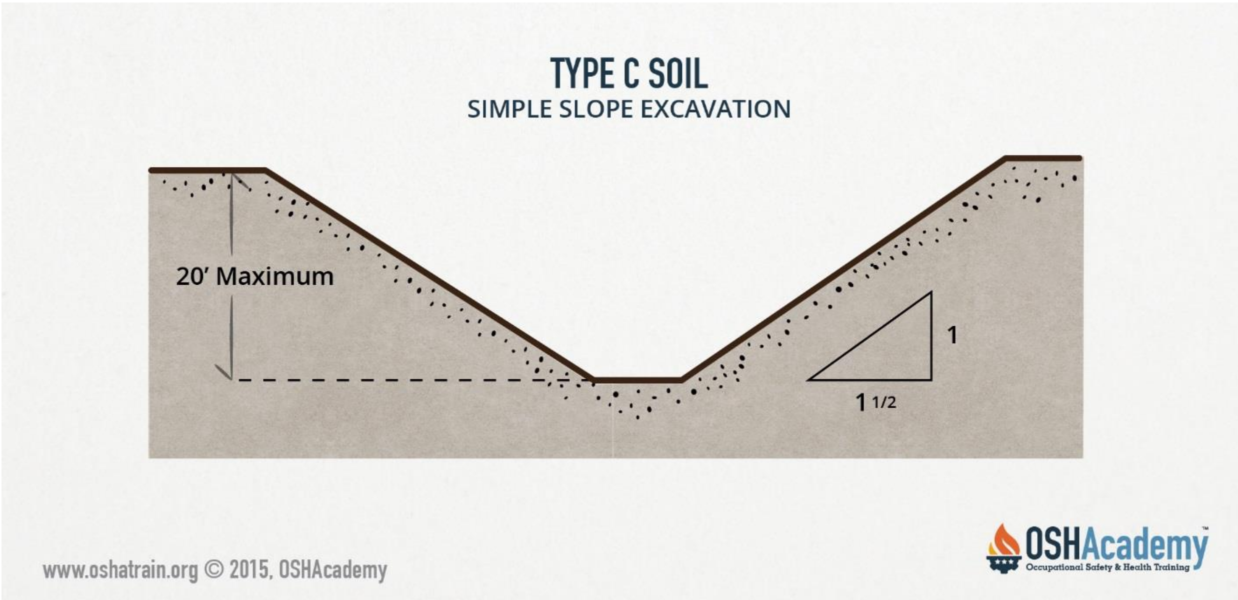
Excavation workers are exposed to many hazards, but the chief hazard is danger of cave-ins. OSHA requires that in all excavations employees exposed to potential cave-ins must be protected by sloping or benching the sides of the excavation, by supporting the sides of the excavation, or by placing a shield between the side of the excavation and the work area.

Designing a protective system can be complex because of the number of factors involved:

- Soil classification
- Depth of cut
- Water content of soil
- Changes due to weather and climate
- Other operations in the vicinity.

The standard, however, provides several different methods and approaches (four for sloping and four for shoring, including the use of shields) for designing protective systems that can be used to provide the required level of protection against cave-ins.

One method of ensuring the safety and health of workers in an excavation is to slope the sides to an angle not steeper than 1½ horizontal to 1 vertical (34 degrees measured from the horizontal) These slopes must be excavated to form configurations that are in accordance with those for Type C soil found in Appendix B of the standard. A slope of this gradation or less is considered safe for any type of soil.



Module 2 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **What is the most common type of soil failure?**

    a. Cave-in
    b. Slides
    c. Erosion at the excavation site
    d. Both A and B are correct

2. **According to the text, ____________ may occur as a result of tension cracks.**

    a. sliding or sluffing
    b. boiling
    c. heaving or squeezing
    d. bulging

3. **If ____________ is/are observed in rocky types of soil, sliding has already occurred.**

    a. silt
    b. cracks
    c. bulging
    d. erosion

4. **One method of ensuring the safety and health of workers in an excavation is to slope the sides to an angle not steeper than ______________.**

    a. two horizontal
    b. three horizontal to one vertical
    c. one and one-half horizontal to one vertical
    d. two and one-half horizontal to one vertical

5. A factor that increases the chances of soil failure is ________.

a. excessive vibration
b. surface encumbrances
c. weather conditions
d. all of the above

Module 3: Soil Types and Pressures

Soil Characteristics

The OSHA excavations standard recognizes and allows a variety of soil classification systems under certain conditions. A special simple soil classification system used by OSHA for excavation planning and protection is included in the standard. If that classification system is strictly followed, trench protection systems can be designed for many situations without the approval of a registered professional engineer.

In the soil classification system used by OSHA, the terms used to identify soil types are drawn largely from another system, commonly used for construction, called the Unified Soils Classification System. Both systems are based upon the engineering properties of soils and are concise and easily associated with actual soil behavior.

The OSHA system can be applied in the laboratory or the field. The terms used for classification are based upon the soil particles, including the quantity of the various sizes of soil particles and the qualities or characteristics of the very fine grains.

The principal types of soil may be divided into two general classes according to grain size. Coarse-grained soils are gravel and sand. Fine-grained soils are silt and clay.

The composition or texture of a soil is a critical factor in its stability. The more cohesive the soil particles; the more the entire soil mass tends to stick together rather than crumble.

However, it is important to remember the time element involved in cuts. If an excavated cut is to be left open for long periods of time, cohesive forces may not withstand exposure to weather conditions.

When fresh fill dirt is not properly compacted, subsequent excavations in the same area result in almost no cohesion properties; thus, a greater width may be required to maintain a stable slope.

Soil Types

The soil found at a site is usually a mixture of one or more of the basic types listed below. From the amounts of each soil type blended together to form the actual soil conditions, descriptive soil terms are combined in the order of lowest content to highest content. For example, soil classified as “silty clay” is a mixture of mostly clay with noticeable but lesser amounts of silt. The single term “loam” is used to describe a mixture of clay, sand and silt.

The types of soil found most often include:

- Clay
    - Clay is a very, very fine-grained soil. In general, water moves slowly through clay. Large amounts of rainfall may pond on the surface and evaporate before being absorbed.
- Sand
    - Sand is a granular soil. The shape of individual grains may be round or angular. Sandy soil tends to have large pores, allowing faster groundwater absorption. In most situations, sandy soil is the easiest to compact with vibration.
- Silt
    - Silt has properties intermediate between fine sand and clay. Silt is the most sensitive to changes in soil moisture content. Silt tends to crumble with drying.

Determination of Soil Type

By grouping different types of soils (described above) according to requirements for safe excavation, the excavation standard has defined four soil classifications (provided below). For a detailed explanation of OSHA classification system, please see Appendix A of the excavation standard.

Stable Rock is natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed. It is usually identified by a rock name such as granite or sandstone. Determining whether a deposit is of this type may be difficult unless it is known whether cracks exist and whether or not the cracks run into or away from the excavation.

OSHA categorizes soil and rock deposits into four types:

1. Stable Rock
2. Type A soils
3. Type B soils
4. Type C soils

Stable Rock

Stable Rock is natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed. It is usually identified by a rock name such as granite or sandstone. Determining whether a deposit is of this type may be difficult unless it is known whether cracks exist and whether or not the cracks run into or away from the excavation.

Type A Soils

These are cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (144 kPa) or greater. Examples of Type A cohesive soils are clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam. (No soil is Type A if it is fissured, is subject to vibration of any type, has previously been disturbed, is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical or greater, or has seeping water.)

Type B Soils

These are cohesive soils with an unconfined compressive strength greater than 0.5 tons per square foot (48 kPa) but less than 1.5 (144 kPa). Examples of Type B soils are angular gravel, silt, silt loam, previously disturbed soils unless otherwise classified as Type C, soils that meet the unconfined compressive strength or cementation requirements of Type A soils but are fissured or subject to vibration, dry unstable rock, and layered systems sloping into the trench at a slope less than four horizontal to one vertical (only if the material would be classified as a Type B soil).

Type C Soils

These are cohesive soils with an unconfined compressive strength of 0.5 tons per square foot (48 kPa) or less. Type C soils include granular soils such as gravel, sand and loamy sand, submerged soil, soil from which water is freely seeping, and submerged rock that is not stable. Also included in this classification is material in a sloped, layered system where the layers dip into the excavation or have a slope of four horizontal to one vertical or greater.

Layered Geological Strata

If soils are configured in layers, the soil must be classified on the basis of the soil classification of the weakest soil layer. Each layer may be classified individually if a more stable layer lies below a less stable layer, (for example, where a Type C soil rests on top of stable rock.)

The standard also contains other important criteria that must be examined to classify soils properly.

Important:

1. The laboratory testing process and compressive strength calculations must be conducted under the direction of a registered professional engineer. The OSHA standard requires that the excavation protection system be designed by a registered professional engineer when the depth of the excavation exceeds 20 feet or where unusual site conditions exist.

2. The manual field testing alternative permitted under the standard does not require the approval of a registered professional engineer under certain specific conditions. However, at least one visual test and one manual test are required to classify soil according to the OSHA method. The specific manual and visual field tests are listed and described in the standard.

Test Equipment and Methods for Evaluating Soil Type

Many kinds of equipment and methods are used to determine the type of soil prevailing in an area, as described below.

Pocket Penetrometer

Penetrometers are direct-reading, spring-operated instruments used to determine the unconfined compressive strength of saturated cohesive soils. Once pushed into the soil, an indicator sleeve displays the reading. The instrument is calibrated in either tons per square foot or kilograms per square centimeter. However, penetrometers have error rates in the range of 20-40 percent.

1. *Shearvane (Torvane):* To determine the unconfined compressive strength of the soil with a shearvane, the blades of the vane are pressed into a level section of undisturbed soil, and the torsional knob is slowly turned until soil failure occurs. The direct instrument reading must be multiplied by 2 to provide results in tons per square foot or kilograms per square centimeter.

2. *Thumb Penetration Test:* The thumb penetration procedure involves an attempt to press the thumb firmly into the soil in question. If the thumb makes an indentation in the soil only with great difficulty, the soil is probably Type A. If the thumb penetrates no further than the length of the thumb nail, it is probably Type B soil, and if the thumb penetrates the full length of the thumb, it is Type C soil. The thumb test is subjective and is therefore the least accurate of the three methods.

3. *Dry Strength Test:* Dry soil that crumbles freely or with moderate pressure into individual grains is granular. Dry soil that falls into clumps that subsequently break into smaller clumps (and the smaller clumps can be broken only with difficulty) is probably clay in combination with gravel, sand or silt. If the soil breaks into clumps that do not break into smaller clumps (and the soil can be broken only with difficulty), the soil is considered non-fissured unless there is visual indication of fissuring.

Module 3 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **According to the text, ___________ is a mixture of mostly clay with noticeable but lesser amounts of silt.**

    a. loam
    b. silty clay
    c. sand
    d. none of the above

2. **Which of the following is a characteristic of clay?**

    a. Water moves quickly through clay
    b. It is a very fine-grained soil
    c. Large amounts of rain may pond on the surface and evaporate before being absorbed
    d. Both B and C are correct

3. **Silt is the most sensitive to changes in soil moisture content.**

    a. True
    b. False

4. **Penetrometers have error rates in what range?**

    a. 20-40 percent
    b. 10-20 percent
    c. 30-40 percent
    d. 15-25 percent

5. **According to the text, the OSHA standard requires the excavation protection system be designed by a registered professional engineer when the depth of the excavation exceeds ____________.**

   a. 10 feet
   b. 15 feet
   c. 20 feet
   d. 35 feet

Module 4: Methods of Protection

Protective Systems

All excavations are hazardous because they are inherently unstable. If they are restricted spaces, they present the additional risks of oxygen depletion, toxic fumes, and water accumulation. If you are not using protective systems or equipment while working in trenches or excavations at your site, you are in danger of suffocating, inhaling toxic materials, fire, drowning, or being crushed by a cave-in.

There are different types of protective systems. Sloping involves cutting back the trench wall at an angle inclined away from the excavation. Shoring requires installing aluminum hydraulic or other types of supports to prevent soil movement and cave-ins. Shielding protects workers by using trench boxes or other types of supports to prevent soil cave-ins. Designing a protective system can be complex because you must consider many factors: soil classification, depth of cut, water content of soil, changes due to weather or climate, surcharge loads (For example, spoil and other materials to be used in the trench) and other operations in the vicinity.

Case Studies

The following case reports of trenching accidents investigated by OSHA only illustrate how seemingly innocent workplace activities can have deadly consequence, especially when it comes to excavation work.

- Two employees were installing 6" PVC pipe in a trench 40' long x 9' deep x 2' wide. No means of protection was provided in the vertical wall trench. A cave-in occurred, fatally injuring one employee and causing serious facial injuries to the other.

- An inadequately protected trench wall collapsed, killing one employee who had just gotten into the trench to check grade for installation of an 8" sewer line. The trench was 20-25 feet deep and had been benched about one bucket-width (4 feet) on each side. At the time of the collapse, a backhoe was still extracting soil from the trench.

- Four employees were in an excavation 32' long x 7' deep x 9' wide boring a hole under a road. Eight-foot steel plates used as shoring were placed against the side walls of the excavation at about 30-degree angles. No horizontal bracing was used. One of the plates tipped over, crushing an employee.

On March 8, 2011, an OSHA investigator was performing a worksite inspection on a trench being dug by Trimat Construction in Mercerville, Ohio. He directed an employee to exit the trench believing collapse was imminent. Within five minutes, the collapse occurred and could have buried the worker under six to seven feet of soil. Workers were ordered out of the trench just moments before a portion collapsed avoiding possible injury or loss of life.

OSHA standards mandate that all excavations 5 feet or deeper be protected against collapse. The employee was working in a trench at a depth greater than 10 feet without cave-in protection. OSHA's investigation is ongoing. The agency will determine why the job was being done in this fashion and what, if any, violations occurred.

Avoiding Hazards

Pre-job planning is very important to prevent these types of accidents when trenching. In other words, safety cannot be improvised as the work progresses.

The following concerns must be addressed by a competent person:

- Evaluate soil conditions and select appropriate protective systems
- Construct protective systems in accordance with the standard requirements
- Pre-Plan: contact utilities (gas, electric) to locate underground lines
- Plan for traffic control, if necessary
- Determine proximity to structures that could affect your choice of protective system
- Test for low-oxygen, hazardous fumes and toxic gas, especially when gasoline engine-driven equipment is running, or the dirt has been contaminated by leaking lines or storage tanks.
- Provide safe access into and out of the excavation

- Inspect the site daily at the start of each shift, following a rainstorm, or after any other hazard-increasing event

Other Safety Precautions

The OSHA standard requires you to provide support systems such as shoring, bracing, or underpinning to ensure that adjacent structures such as buildings, walls, sidewalks, or pavements remain stable. The standard also prohibits excavation below the base or footing of any foundation or retaining wall unless:

- You provide a support system such as underpinning,
- The excavation is in stable rock, or
- A registered professional engineer determines the structure is far enough away from the excavation and the excavation will not pose a hazard to employees.

Excavations under sidewalks and pavements are prohibited unless you provide an appropriately designed support system or another effective means of support. There must not be any indications of a possible cave-in (while the trench is open) below the bottom of the support system. Also, you must coordinate the installation of support systems closely with the excavation work.

Once the work is finished, you are required to backfill the excavation when you take apart the protective system. After the excavation is cleared, remove the protective system from the bottom up. Make sure you are careful! In the next module, you'll learn more about safely installing and removing protective systems.

Maintaining Materials and Equipment for Protective Systems

You are responsible for maintaining materials and equipment used for protective equipment. Defective and damaged materials and equipment can cause failure of a protective system and other excavation hazards.

To avoid possible failure of a protective system, you must make sure that:

- Materials and equipment aren't damaged or defective
- Manufactured materials and equipment are used and maintained consistent with the manufacturer's recommendations

- A competent person examines all damaged materials and equipment. Unsafe materials and equipment must be removed from service until a registered professional engineer evaluates and approves them for use

Residential Contractors and the Excavations Standard

An estimated 1.6 million Americans are employed in the construction industry, half of which work in residential construction. Each year, about 38,000 construction injuries are reported in the United States. Many OSHA standards apply to residential construction for the prevention of possible fatalities. The federal Department of Labor (DOL) has recognized that residential construction sites can be very different from commercial sites as they relate to part of the OSHA Excavations Standard (29 CFR 1926.652).

To address accepted residential building practices as they relate to the standard, the DOL has created occupational safety and health enforcement policies for excavations on residential sites. However, the DOL's policy suspends the standard for house foundation and basement excavations at residential sites when ALL the following conditions are present:

- The house foundation/basement excavation is less than 7 ½ feet in depth or is benched for at least 2 feet horizontally for every 5 feet or less of vertical height.
- The minimum horizontal width at the bottom of the excavation is as wide as needed, but not less than 2 feet.
- There is no water, surface tension cracks or other environmental conditions present that reduce the excavation stability.
- There is no heavy equipment operating in the vicinity that causes vibration to the excavation while employees are in the excavation.
- Work crews in the excavation are the minimum number needed to perform the work.
- The work has been planned and is carried out in a manner to minimize the time employees are in the excavation.

That's it for this module. Let's move on to your next quiz!

Module 4 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **According to the text, if you aren't using protective systems while working in trenches or excavations, you may be in danger of ________.**

    a. suffocating
    b. inhaling toxic materials
    c. being fined by OSHA
    d. Both A and B are correct

2. **_______ involves cutting back the trench wall at an angle inclined _________ the excavation.**

    a. Sloping, away from
    b. Shoring, towards
    c. Trenching, near
    d. Sloping, towards

3. **Shoring requires installing aluminum hydraulic supports to prevent soil movement and cave-ins.**

    a. True
    b. False

4. **The OSHA standard prohibits excavation below the base or footing of any foundation or retaining wall, unless ________.**

    a. you provide a support system
    b. the excavation is in stable rock
    c. a registered engineer determines the structure is far enough away from the excavation
    d. both a and b are correct
    e. All the above

5. To avoid possible failure of a protective system, you must make sure that _______________.

a. materials and equipment aren't damaged or defective
b. manufactured materials and equipment exceed the manufacturer's safety recommendations
c. a competent person examines most of the damaged materials and equipment.
d. Both B and C are correct

Module 5: Installation and Removal of Protective Systems

You must take the necessary steps to protect yourself and your employees when installing and removing a protective system. The OSHA standard requires you to take the following steps to protect your employees:

- Connect members of the support systems securely.
- Install support systems safely.
- Avoid overloading members of support systems.
- Install other structural members to carry loads imposed on the support system when you need to remove individual members temporarily.

In addition, the standard permits excavation of two feet or less below the members of a support or shield system of a trench if the system is designed to resist the forces calculated for the full trench depth.

Appropriate Protective System Designs

Designing a protective system can be complex. You **must** consider many factors, including:

1. soil classification
2. depth of cut
3. water content of soil
4. changes due to weather and climate
5. other operations in the vicinity

Once you have selected an approach, however, the system must meet the required OSHA performance criteria.

The OSHA standard describes methods and approaches for designing protective equipment. Let's discuss the different methods to designing protective equipment.

Method 1: Sloping

Slope the sides to an angle that isn't steeper than 1½:1. For example, for every foot of depth, the trench must be excavated back 1½ feet. All simple slope excavations 20 feet or less deep should have a maximum allowable slope of 1½:1. These slopes must be excavated to form configurations similar to those for Type C soil. A slope of this gradation or less is safe for any type of soil.

Method 2: Design using data

Use tabulated data such as tables and charts approved by a registered professional engineer to design excavation. This data must be in writing and must include enough information, including the criteria for making a selection and the limits on the use of the data.

At least one copy of the data, including the identity of the registered professional engineer who approved it, must be kept at the worksite during the construction of the protective system.

After the system is completed, the data can then be stored away from the jobsite. However, a copy must be provided upon request to the Assistant Secretary of Labor for OSHA.

Method 3: Trench box or shield

In this method, you would use a trench box or shield designed or approved by a registered professional engineer. Timber, aluminum, or other suitable material may also be used in the construction. OSHA standards permit the use of a trench shield if it provides the same level of protection as the appropriate shoring system.

Employers can choose the most practical method for the particular circumstance, but that system must meet the required performance criteria. The standard doesn't require a protective system when an excavation is made entirely in stable rock or is less than five feet deep. However, in this case, a competent person must examine the ground and find no indication of a potential cave-in.

Entering and Exiting the Excavation

As mentioned earlier, an excavation that has a depth of four feet or more must have a way to enter and exit the excavation. You can use a stairway, ladder, or a ramp. They need to be within 25 feet of employees; their safety may depend on how quickly they can climb out of an excavation. These structural ramps that are used to enter and exit the site must have non-slip surfaces and be designed by a competent person. A competent person must also evaluate ramps made from soil that are used to enter and exit an excavation.

Sloping

One method of trench protection can be accomplished by sloping the sides of the trench to a safe angle. The trench is sloped on both sides. The safe angle to slope the sides of an excavation varies with different kinds of soil. The safe angle must be determined with each individual project. When an excavation is near water, has silty material or loose boulders, or when it is being dug in areas where erosion, deep frost or sliding is probable, the safe angle is more gradual.

Sloping Problems

Although sloping and benching is a good method for excavations, there are still some problems you may encounter. For example, wide excavation areas can expose footings or cause damage to the walls of the adjacent structure and pose additional hazards to employees. Wide excavation areas can also expose or place utilities (such as electrical power, water, and gas lines) above the angle for a safe slope. They also require the use of large equipment. There may also be hazards in the movement of the equipment across a larger excavation.

To prevent the collapse of an unsupported bench in an excavation 8 feet or less in depth, the allowable height of a bench at the base of an excavation must be 3 ½ feet or less. The collapse of one bench can, in turn, cause a lower bench to fail in a situation where many benches have been created. For Type A soil, for example, the OSHA standard requires multiple benches to have an overall slope of ¾ inches horizontal to 1 inch vertical.

The contractor needs to make a determination of the soil types at the excavation site using the soil classification system discussed in Module 2. Next, the contractor could consider potential sloping and benching problems, such as those mentioned above. Finally, after considering all other protection that may be necessary to ensure safe working conditions, the contractor can then determine if sloping is the best method to use at the site.

Benching

There are two basic types of benching: simple and multiple. The type of soil determines the horizontal to vertical ratio of the benched side. As a general rule, the bottom vertical height of the trench must not exceed 4 feet. However, subsequent benches may be up to a maximum of 5 feet vertical in Type A soil and 4 feet in Type B soil. All subsequent benches must be below the maximum slope allowed for that soil type. Also, in Type B soil, the trench excavation is permitted only in cohesive soil.

Shoring Types

Shoring is the part of a support system for trench faces. It is used to prevent movement of soil, underground utilities, roadways and foundations. Shoring or shielding is used when the location or depth of the cut makes sloping back to the maximum allowable slope impractical. Shoring consists of posts, struts and sheeting. There are two types of shoring: timber and aluminum hydraulic.

Hydraulic Shoring

This seems to be more of a trend today. Hydraulic shoring, a pre-fabricated strut and/or wale system made from aluminum or steel. Hydraulic shoring provides a critical safety advantage over timber shoring because workers do NOT have to enter the trench to install or remove hydraulic shoring.

Other advantages to most hydraulic systems include:

- Light enough to be installed by one worker
- Gauge-regulated to ensure even distribution of pressure along the trench line
- Can have their trench faces “pre-loaded” to use the soil’s natural cohesion to prevent movement
- Can be adapted easily to various trench depths and widths

All shoring should be installed from the top down and removed from the bottom up. Hydraulic shoring should be checked at least once per shift for leaking hoses and/or cylinders, broken connections, cracked nipples, bent bases, and other damaged or defective parts.

Pneumatic Shoring

Pneumatic shoring works in a manner similar to hydraulic shoring. The primary difference is pneumatic shoring uses air pressure in place of hydraulic pressure. However, you need to have an air compressor on site when using pneumatic shoring. Air shoring involves using compressed air instead of hydraulic fluid to expand the trench jacks into position. Using the air type of system, pins are put in place to lock the jacks when a desired level of stability is achieved. To remove this type of trenching system, air is injected into the jacks to extend them. This allows the pin to be removed. These types of jacks are popular since they are cleaner than hydraulic jacks and there isn’t a danger from the leakage of fluids or other lubrication.

Support Systems, Shield Systems & Other Protective Systems

As mentioned earlier, when a trench is excavated, employees who work in the area MUST be protected from cave-ins. Therefore, the contractor should consider excavating a wider area than the necessary minimum. When this is done, it provides a more comfortable working environment for your employees in the trench. In addition, this extra working area may provide a way for workers to escape an unexpected crisis, such as falling objects or debris. Contractors should also reduce risk by limiting the number of workers in the trench at all times. The only workers allowed in the trench should be those who are absolutely needed to perform the task at hand.

As the trench is backfilled, the braces and planks can be removed to be used at another site. If installed and removed correctly, vertical planks and trench braces may be used several times!

Module 5 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **The OSHA standard requires you to _________ in order to protect your employees.**

    a. connect members of the support systems securely
    b. avoid overloading members of the support system
    c. install support systems safely
    d. all the above

2. **According to the text, you MUST consider ________ when constructing a protective system.**

    a. soil classification
    b. depth of cut
    c. where the contractor wants to place a protective system
    d. Both a and b are correct

3. **An excavation that has a depth of ________ must have a way to enter and exit the excavation.**

    a. four feet or more
    b. two feet
    c. less than one foot
    d. three feet

4. **According to the text, structural ramps used to enter and exit the site must have ___________ and be designed by a ___________.**

    a. slip surfaces, non-competent person
    b. non-slip surfaces, competent person
    c. stairs, supervisor
    d. handrails, employee

5. Contractors should also reduce risk by limiting the ____________ in the trench at all times.

a. number of workers
b. the amount of shoring
c. number of benches
d. posts and struts

Module 6: Jobsite Safety and Worker Training

One of the most important responsibilities of field and office management is planning for safety. Most on-the-job problems and accidents directly result from improper planning. Correcting mistakes in shoring and/or shoring after work has started slows down the operation, adds to the cost and increases the possibility of an excavation failure.

Contractors should develop safety checklists to make certain there is enough information about the jobsite and all needed items, such as safety equipment, are on hand.

To help ensure safety in trenching and excavations, you will need to take these specific conditions into account:

- soil types and layers
- traffic
- nearness of structures and their condition
- surface and ground water conditions
- the water table evaluation
- overhead and underground utilities
- weather

These and other conditions can be determined by jobsite studies, observations and consultations with local officials and utility companies. Underground installations, such as sewer, telephone, water, fuel and electrical lines, need to be found before starting a job. If underground installations are found, OSHA regulations require they must be properly supported.

The contractor MUST contact the utility companies involved and inform them of the work before starting the trench or excavation. This should be done at least two business days before you begin your work.

The utility will help you with certain tasks, such as the following, to make sure you are safe:

- Coordinate work schedules

- Identify temporary mechanical barriers that prevent contact with the lines.
- De-energize and ground the lines.
- Temporarily raise or move the lines.

You're responsible for all damages and costs that result from an electrical accident. Also, there could be a penalty from OSHA of up to $70,000 for each offense in addition to the cost of injuries and repairs!

Employee Training

Cooperation between supervisors and employees is necessary to make sure safety policies are implemented effectively. Each supervisor must understand his or her degree of responsibility for providing a safe working environment.

The cooperation of all employees requires their recognition of safety hazards and the needed safety precautions.

Employees need to be trained in the following areas:

1. trenching and excavating hazards
2. soil identification
3. safe slopes for different soil types and conditions
4. stress patterns on trench walls from soil and spoil, equipment, and vibration caused by equipment and traffic
5. effects of nearby buried utilities, building foundations and lengthy exposure to the elements on trench side walls and other excavations
6. effects on trench and excavation conditions from severe weather (such as excess water, freezing temperatures, unexpected heat or long-term drying)
7. recognition of buried drums, containers, tanks and wells

Employees also need to be trained to follow the proper procedures to involve the electrical power company, health department and other agencies when they find unforeseen objects, such as wells, sewage disposal systems, cemeteries, and historical or architectural artifacts.

On-the-Job Follow-up

Once the job begins, each employer should stay informed of the safety aspects of the project as well as the progress of the work. This is called "on-the-job follow-up" and involves a series of inspections to find potential hazards and correct them before cave-ins or other accidents happen at the site. When management requires daily reports and then acts on them, it then makes everyone feel more confident that everyone is meeting job safety responsibilities.

Surface Crossing of Trenches

Surface crossing of trenches should be discouraged; however, if trenches must be crossed, they are only permitted under the following conditions:

- Vehicle crossings must be designed and installed under the supervision of a registered professional engineer.
- Walkways or bridges must be provided for foot traffic. These structures must:
    - have a minimum clear width of 20 inches
    - be fitted with standard rails
    - extend a minimum of 24 inches past the surface edge of the trench

Exposure to Falling Loads

Employees must be protected from loads or objects falling from lifting or digging equipment.

Here are some procedures to protect your employees:

- Employees are not permitted to work under raised loads.
- Employees are required to stand away from the equipment that is being loaded or unloaded.
- Equipment operators or truck drives may stay in their equipment during loading and unloading, if the equipment has a cab shield or adequate canopy.

Standing Water and Water Accumulation

Methods for controlling standing water and water accumulation must be provided.

The methods should consist of the following, if employees are permitted to work in the excavation:

- use of special support or shield systems approved by a registered professional engineer
- water removal equipment, i.e., well pointing, used and monitored by a competent person
- safety harnesses and lifelines used
- surface water diverted away from the trench
- employees removed from the trench during rainstorms
- trenches carefully inspected by a competent person after each rain and before employees are permitted to re-enter the trench

There are some hazards stemming from water in an excavation. For example, the contractor may undermine the sides and make it more difficult to get out of the excavation.

The OSHA Standard prohibits employees from working without adequate protection in excavations where water has accumulated or is accumulating. If you use water removal equipment to control or prevent water accumulation, you must make sure a competent person monitors the equipment and its operation to ensure proper use.

OSHA standards also require the use of diversion ditches, dikes and other suitable means to prevent water from entering an excavation and to provide drainage of the adjacent area. A competent person must also inspect those excavations that are subject to runoffs from heavy rains.

Scenario

Two employees were installing storm drain pipes in a trench, approximately 20-30 feet long, 12-13 feet deep and 5-6 feet wide. The side walls consisted of unstable soil undermined by sand and water. There was 3-5 feet of water in the north end of the trench and 5-6 inches of water in the south end. At the time of the accident, a backhoe was being used to clear the trench. The west wall of the trench collapsed, and one employee was crushed and killed.

Inspection Results

As result of the investigation, OSHA issued citations for one willful, one serious, and one-other-than-serious violation of its construction standards.

OSHA's construction safety standards include several requirements which, if they had been followed here, might have prevented this fatality.

Accident Prevention Recommendations

1. Employers must shore, slope sheet or brace sides of trenches in unstable material (29 CFR 1926.652(b) or 1926.651(c)).

2. There must be a means of escape from a trench such as ladder (29 CFR 1926.652(h)).

3. Trench work is to be inspected daily by a "competent person". When there's evidence of cave-ins or slides, all work must stop (29 CFR 1926.650(i)).

4. Water must not be allowed to accumulate in a trench (29 CFR 1926.651(p)).

5. Excavation material must be moved at least two feet from the edge of the trench (29 CFR 1926.651(i)).

6. Where heavy equipment is operating near a trench, extra precautions must be taken due to the extra load imposed on the ground (29 CFR 1926.651(q)).

Hazardous Atmospheres Inside Excavations

Also, OSHA has specific training requirements for all employees who are required to enter confined or enclosed spaces.

A competent person must test an excavation deeper than 4 feet or where an oxygen deficiency or hazardous atmosphere is present or could reasonably be expected before an employee enters the excavation. This could include a landfill or where hazardous substances are stored nearby.

If there are any hazardous conditions, you must provide the employee controls, such as proper respiratory protection or ventilation. Also, you are responsible for regularly testing all controls used to reduce atmospheric contaminates to acceptable levels.

If unhealthful atmospheric conditions exist or develop in an excavation, you must provide emergency rescue equipment such as breathing apparatus, safety harness and line, and basket stretcher. Make sure this equipment is readily available, in case of an emergency.

Conducting an On-site Inspection

The OSHA standard requires a competent person to inspect an excavation daily. They need to watch for possible cave-ins, failures of protective systems and equipment, hazardous atmospheres, or other hazardous conditions. Inspections also are required after natural events such as heavy rains or manmade events such as blasting that may increase the potential for hazards. If the inspector finds any unsafe conditions during an inspection, you must clear employees from the hazardous area until you take safety precautions.

If the competent person finds any hazardous conditions, all exposed employees must leave the hazardous area until necessary safety precautions are taken.

Larger and more complex operations should have a full-time safety official who makes recommendations to improve implementation of the safety plan. In a smaller operation, the safety official may be part-time and usually will be a supervisor.

Supervisors are the contractor's representatives on the job. Supervisors should conduct inspections, investigate accidents, and anticipate hazards. They should ensure that employees receive on-the-job safety and health training. They also should review and strengthen overall safety and health precautions to guard against potential hazards, get the necessary worker cooperation in safety matters, and make frequent reports to the contractor.

Module 6 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. **Most on-the-job problems and accidents directly result from ________.**

   a. lack of employee training
   b. improper planning
   c. incompetent contractors
   d. lack of supervisors on site

2. **The contractor does NOT have to contact the utility companies to inform them of the work before starting the trench or excavation.**

   a. True
   b. False

3. **In regard to excavation and trenching, employees need to be trained in ________.**

   a. trenching and excavation hazards
   b. CPR and first aid
   c. safe slopes for different soil types and conditions
   d. both A and C are correct

4. **The OSHA standard requires a competent person to inspect an excavation ___________.**

   a. every hour if conditions don't change
   b. daily and whenever conditions change
   c. once a week if conditions don't change
   d. once every two days and whenever conditions change

5. **Walkways or bridges must be provided for foot traffic. These structures must ________.**

   a. have a minimum clear width of 30 feet
   b. be fitted with standard rails
   c. extend a minimum of 30 inches past the surface edge of the trench
   d. none of the above