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.

OSHAcademy Course 802 Study Guide

Excavation Safety

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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Contents

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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: The Basics

Introduction

Excavation and trenching are among the most hazardous construction operations. The Occupational Safety and Health Administration's (OSHA) Excavation standards, 29 Code of Federal Regulations (CFR) Part 1926, Subpart P, contain requirements for excavation and trenching operations. The OSHA standard applies to all open excavations made in the earth's surface, which includes trenches.

Excavations and Trenches

Excavations. OSHA defines an excavation as any man-made cut, cavity, trench, or depression in the Earth's surface formed by earth removal.

Trenches. A trench is defined as a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth of a trench is greater than its width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m).

The Dangers of Trenching and Excavation Operations

Trenching and excavation work presents serious hazards to all workers involved.

- Cave-ins pose the greatest risk and are more likely than some other excavation-related incidents to result in worker fatalities. One cubic yard of soil can weigh as much as a car. An unprotected trench can be an early grave. Employers must ensure that workers enter trenches only after adequate protections are in place to address cave-in hazards.

- Other potential hazards associated with trenching work include falling loads, hazardous atmospheres, and hazards from mobile equipment.

1. What does OSHA's excavation standard apply to?

a. Trenches two feet deep and three feet wide
b. All open excavations made in the earth's surface, which includes trenches
c. House foundation excavations less than 7 1/2 feet deep
d. Trenches two feet deep and four feet wide

The Standards

29 CFR 1926.650, 29 CFR 1926.651, and 29 CFR 1926.652 are applicable OSHA standards.

The standard also provides several appendices:

- Appendix A, Soil Classification
- Appendix B, Sloping and Benching
- Appendix C, Timber Shoring for Trenches
- Appendix D, Aluminum Hydraulic Shoring for Trenches
- Appendix E, Alternatives to Timber Shoring
- Appendix F, Selection of Protective Systems

The Basic Strategies

OSHA has made reducing trenching and excavation hazards the Agency's Priority Goal. Trench collapses, or cave-ins, pose the greatest risk to workers' lives. To prevent cave-ins:

1. **SLOPE** or bench trench walls by cutting back the trench wall at an angle inclined away from the excavation;
2. **SHORE** trench walls by installing aluminum hydraulic or other types of supports to prevent soil movement; or
3. **SHIELD** trench walls by using trench boxes or other types of supports to prevent soil cave-ins.

Employers should also ensure there is a safe way to enter and exit the trench. Keep materials away from the edge of the trench. Look for standing water or atmospheric hazards. Never enter a trench unless it has been properly inspected.

2. To prevent trench cave-ins, OSHA recommends each of the following controls EXCEPT _____.

a. sloping
b. shoring
c. covering
d. shielding

Competent Person (CP) Responsibilities

Proper selection and installation of trench protection measures require the involvement of a competent person (CP). OSHA defines competent person as:

"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."

The CP has important excavation inspection responsibilities:

- Determine cave-in potential to assess the need for shoring or other protective systems;
- Classify soil and rock deposits;
- Determine the appropriate slope of an excavation to prevent collapse;
- Assess entry and exit methods such as ladders and structural ramps;
- Inspect the excavation and protective system at least daily before the start of work and as needed throughout a workshift.
- Inspect when any hazard-increasing occurrence (such as a rainstorm) takes place.
- Remove employees from the danger area if evidence of a possible cave-in, protective system failure or any other hazardous condition, exists.
- Monitor water removal equipment and operations and inspect excavations subject to runoff from heavy rains

3. How often should a competent person inspect excavations and protective systems for which they are responsible?

a. Weekly during prolonged projects
b. Every two days or more often if required
c. Hourly during the workshift during rainy periods
d. Daily before the start of work and as needed

Preplanning

No matter how many trenching, shoring, and backfilling jobs an employer has done in the past, it is important to approach each new job with care and preparation. Many on-the-job incidents result from inadequate initial planning. Waiting until after the work starts to correct mistakes in sloping, shoring, or shielding slows down the operation, adds to the cost of the project, and makes a cave-in or other excavation failure more likely.

Before preparing a bid, employers should know as much as possible about the jobsite and the materials they will need to have on hand to perform the work safely and in compliance with OSHA standards. For instance, if you were bidding on a job to replace an underground utility line, you might assume that the soil covering the line would not be Type A (more on soil types in Module 3) because it is previously disturbed soil. However, you would always want to analyze the soil just to make sure.

Employers can gather the information they need through jobsite studies, observations, test borings for soil type or conditions, and consultations with local officials and utility companies. This information will help employers determine the amount, kind, and cost of safety equipment they will need to perform the work safely.

Employers should do what's necessary to avoid hitting underground utility lines and pipes during excavation work.

Here are some of the employer actions that OSHA requires:

- Determine the approximate location(s) of utility installations — including sewer, telephone, fuel, electric, and water lines. One common industry practice is to call 811, the "Call Before You Dig" number, to establish the location of any underground utility installations in the work area.

- Contact and notify the utility companies or owners involved to inform them of the proposed work within established or customary local response times.

- Ask the utility companies or owners to establish the location of underground installations prior to the start of excavation work. If they cannot respond within 24 hours (unless the period required by state or local law is longer) or cannot establish the exact location of the utility installations, employers may proceed with caution, which includes using detection equipment or other acceptable means to locate utility installations.

- Determine the exact location of underground installations by safe and acceptable means when excavation operations approach the approximate location of the installations.
- Ensure that while the excavation is open, underground installations are protected, supported or removed as necessary to safeguard workers.

4. When planning a project that involves digging a trench be sure to _____.

a. only dig one foot before checking for lines
b. ask utility companies to check for lines daily
c. assume the soil type for each trench
d. call 811 before digging

Safety Factors to Consider When Bidding

Before preparing a bid, employers should know as much as possible about the jobsite and the materials they will need to have on hand to perform the work safely and in compliance with OSHA standards. A checklist may prove helpful to identify safety requirements for new projects.

A safety checklist may prove helpful when employers are considering new projects. You can view an example of an excavation checklist at OSHA's Guide for Daily Inspection of Trenches and Excavations.

Safety Factors

Factors to consider may include:

- Traffic
- Proximity and physical condition of nearby structures
- Soil classification
- Surface and ground water
- Location of the water table
- Overhead and underground utilities
- Weather

- Quantity of shoring or protective systems that may be required
- Fall protection needs
- Number of ladders that may be needed
- Other equipment needs

Employers can gather the information they need through jobsite studies, observations, test borings for soil type or conditions, and consultations with local officials and utility companies. This information will help employers determine the amount, kind, and cost of safety equipment they will need to perform the work safely.

5. Which planning tool may prove helpful to identify safety requirements for new projects?

a. An audit
b. A checklist
c. An assessment
d. A consultation

Written Policies

Many companies have established a written policy that outlines specific safe trenching practices in detail. An effective policy should ensure adequate support for the trench is installed and that frequent inspections of the excavation site are conducted 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.

Sound policies can be grouped into three major categories. Write policies to:

- **Prepare** a safe trench. Provide safe entry and exit before starting work. Keep materials at least 2 feet away from the edge.
- **Protect** workers from a cave-in by using protective systems. Sloping or benching trench walls, shoring the trench walls with supports, or shielding trench walls with trench boxes.

- **Inspect** the trench for hazards. Look for standing water and other environmental hazards. Never enter a trench unless it has been inspected and approved by the competent person.

Click on the link to download a sample Excavation Program from the Texas Dept. of Insurance.

6. What should a safe trenching policy ensure?

a. All soils are considered Class I
b. Frequent inspections are conducted
c. No more than 10 employees in the trench
d. Heavy vehicles parked next trenches are chocked

Scenario

Two construction laborers 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 that the trench had collapsed, and the two employees were buried.

The crew leader summoned the emergency medical services (EMS) who responded within minutes.

Coworkers uncovered the victims and removed them from the trench as the EMS arrived. However, the victims could not be revived.

Findings

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 2: Soil Characteristics and Types

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:

1. **Fine-grained soils** - silt and clay; and
2. **Coarse-grained soils** - gravel and sand.

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.

1. Soils are classified into two general categories based on _____.

a. hardness
b. weight
c. grain size
d. cohesion

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:

1. **Loose soil** is any type of soil that has been worked or disturbed so that it is not compacted.

2. **Sand** is a granular soil. The shape of individual grains may be round or angular. Sandy soil tends to have large pores, allowing faster ground absorption. In most situations, sandy soil is the easiest to compact with vibration.

3. **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.

4. **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.

5. **Loam** is a combination of sand, silt, and clay such that the beneficial properties from each is included.

Definitions

Cemented soil means a soil in which the particles are held together by a chemical agent, such as calcium carbonate, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure.

Cohesive soil means clay, or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist.

Dry soil means soil that does not exhibit visible signs of moisture content.

Fissured means a soil material that has a tendency to break along definite planes of fracture with little resistance, or a material that exhibits open cracks, such as tension cracks, in an exposed surface.

Granular soil means gravel, sand, or silt with little or no clay content. Granular soil has no cohesive strength, though some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

Granular cohesionless soil means soil that contains less than 85% sand and gravel but does not contain enough clay to be molded.

Layered system means two or more distinctly different soil or rock types arranged in layers. Micaceous seams or weakened planes in rock or shale are considered layered.

Moist soil means a condition in which a soil looks and feels damp. Moist cohesive soil can easily be shaped into a ball and rolled into small diameter threads before crumbling. Moist granular soil that contains some cohesive material will exhibit signs of cohesion between particles.

Plastic means a property of a soil which allows the soil to be deformed or molded without cracking, or appreciable volume change.

Saturated soil means a soil in which the voids are filled with water. Saturation does not require flow. Saturation, or near saturation, is necessary for the proper use of instruments such as a pocket penetrometer or sheer vane.

Soil classification system means, for the purpose of this subpart, a method of categorizing soil and rock deposits in a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing order of stability. The categories are determined based on an analysis of the properties and performance characteristics of the deposits and the environmental conditions of exposure.

Stable rock means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Submerged soil means soil which is underwater or is free seeping.

2. Which soil type is a granular, has large pores, and is easy to compact?

a. Gravel
b. Clay
c. Silt
d. Sand

Unit Weight of Soils

The unit weight of soils 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.

The maximum weights will be reached when the soil is wet. See examples of the weight of one cubic meter for the five types soils:

- **Loose dirt** can weigh up to 2690 lb (1220 kg);
- **Loam** can weigh up to 2800 lb (1270 kg);
- **Sand** can weigh up to 3428 lb (1555 kg);
- **Clay** can weigh up to 3527 lb (1600 kg); and
- **Gravel** can weigh up to 3704 lb (1680 kg).

3. Which soil type has the greatest maximum weight per cubic meter?

a. Sand
b. Gravel
c. Clay
d. Loam

Determination of Soil Type

By grouping different types of soils (described in the previous sections of this module) 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.

OSHA groups soil and rock deposits into four classifications: Stable rock, Type A soils, Type B soils, and 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

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. Cemented soils such as caliche and hardpan are also considered Type A.

However, no soil is Type A if:

- Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (144 kPa) or greater.
- The soil is fissured; or
- The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or
- The soil has been previously disturbed; or
- The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater; or
- The material is subject to other factors that would require it to be classified as a less stable material.

Type B Soils

Examples of Type B soil include angular gravel, silt, silt loam, and soils that are fissured or near sources of vibration, but could otherwise be Type A.

Type B soils are defined as meeting any of the following:

- Cohesive soils with an unconfined compressive strength greater than 0.5 tons per square foot (48 kPa) but less than 1.5 (144 kPa)
- Angular cohesionless soils including: angular gravel (similar to crushed rock).

- Previously disturbed soils except those which would otherwise be classed as Type C soil.
- Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or
- Dry rock that is not stable; or
- Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

Type C Soils

Type C soil is the least stable type of soil and include granular soils in which particles don't stick together and cohesive soils with a low unconfined compressive strength; 0.5 tons per square foot or less. Examples of Type C soil include gravel, and sand. Because it is not stable, soil with water seeping through it is also automatically classified as Type C soil, regardless of its other characteristics.

Type C soils are defined as meeting any of the following:

- Cohesive soils with an unconfined compressive strength of 0.5 tsf (48 kPa) or less>
- Granular soils including gravel and sand;
- Soils that have been disturbed;
- Submerged soil or soil from which water is freely seeping;
- Submerged rock that is not stable; or
- Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical (4H:1V) or steeper.

4. Which of the following is considered Type A cohesive soil?

a. Clay
b. Sand
c. Silt
d. Loam

Layered Geological Strata

Accident Prevention Recommendations

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.
2. The OSHA standard requires that the excavation protection system be designed by a registered professional engineer when the depth of the excavation exceeds <u>20 feet</u> or where <u>unusual site</u> conditions exist.
3. 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.

5. If soils are configured in layers, the soil must be classified on the basis of the soil classification of _____.

a. the topsoil layer
b. the weakest soil layer
c. the base soil layer
d. the most cohesive layer

Methods for Evaluating Soil Type

Site Soil Analysis

An analysis of conditions around the site is conducted by observing soil adjacent to the site and the soil being excavated. If the soil remains in clumps, it is cohesive; if it appears to be coarse-grained sand or gravel, it is considered granular. The evaluator also checks for any signs of vibration.

During the analysis, the evaluator should check for crack-line openings along the failure zone that would indicate tension cracks, look for existing utilities that indicate that the soil has previously been disturbed, and observe the open side of the excavation for indications of layered geologic structuring.

The evaluator should also look for signs of bulging, boiling, or sluffing, as well as for signs of surface water seeping from the sides of the excavation or from the water table. The area adjacent to the excavation should be checked for signs of foundations or other intrusions into the failure zone, and the evaluator should check for surcharging and the spoil distance from the edge of the excavation.

Test Methods

When performing a soil test, it's important to choose a good soil sample. Soil samples should be typical of the surrounding soil in the excavation, and additional samples should be taken as the excavation gets deeper. While the excavation wall is one place to take samples, OSHA recommends taking a large clump from the excavated pile, as long as the soil in the pile is fresh and hasn't been compacted. Test results can change as the soil dries up, so for the best results, samples should be taken and tested as soon as practical. Let's look at three main types of soil tests.

Plasticity or Wet Thread Test

The plasticity (cohesiveness) test, which is sometimes called the pencil test, is used to determine if the soil is cohesive.

- This test is performed by rolling a moist soil sample into a thread that's one-eighth of an inch (3 mm) thick and two inches (5 cm) long, resembling a short, slim pencil.
- If the sample can be held at one end without breaking, it is cohesive.
- Any soil that is not cohesive is automatically classified as Type C, although some Type C soils are cohesive.

Thumb Penetration Test

The thumb penetration test is used to quickly estimate the compressive strength of a cohesive soil sample. To perform the thumb penetration test, simply press the end of your thumb into a fresh clump of soil.

- If the soil sample is Type A, your thumb will only make an indentation in the soil with great effort, as you can see demonstrated here.

- If the soil sample is Type B, your thumb will sink into the soil up to the end of your thumbnail, just like this.

- If the soil sample is Type C, your thumb will sink all the way into the soil clump, as you can see here.

Your results for this test will probably be somewhere in between these results.

Dry Strength Test

This test is usually conducted on a small sample of dried soil 1/2 inch think and 1 1/2 in diameter. After the sample is thorough dry, try to break it using the thumbs and forefingers of both hands.

- 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.

Pocket Penetrometer Test

For a more numeric measurement, the pocket penetrometer test can be used. A soil's compressive strength can be given a numeric value by using the pocket penetrometer test. There can be some variability (± 20-40%) in these results, so it's a good idea to run this test on a few soil samples from the same part of the excavation, just to make sure your results are consistent.

- A pocket penetrometer works much like a tire pressure gauge.

- A thin, metal piston is pushed into a soil sample, and the penetrometer records the compressive strength of the soil.

- Be sure that the scale indicator is inserted into the penetrometer body until only the "zero" mark is showing.

- To conduct the test, push the piston into the soil until it reaches the engraved line. Then, simply take the reading from the scale indicator.

- It's important to recognize that a penetrometer may give false results if the soil contains rocks or pebbles, which won't compress.

6. OSHA does NOT recommend taking soil to be tested from _____.

a. a large clump of soil
b. soil from an excavated pile
c. soil that has been compacted
d. soil that is fresh

Module 3: Why Soil Fails

Soil failure. Soil failure is defined as the collapse of part or all of an excavation wall.

Safe slope. 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.

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

Complicating Factors

There are other complicating factors that can result in soil failures.

- **Layering**. 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 safe slope for the different soil types and layers encountered during the excavation.

- **Soil composition**. 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.

1. What is the most common cause leading to soil failure?

a. Settlement
b. Flaking off
c. Sliding
d. Layering

Sliding Problems

Sliding and other modes of failure can occur in soils that are not densely compacted.

- If a trench that is made close to a previously dug trench is very unstable.

- If uncompacted soil is discovered, the normal safe slope for dense soil will not be enough to prevent sliding. Bracing or more gradual sloping may be necessary.

- If tension 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.

- If, after prolonged exposure to the elements, the moisture content in stable soil may increase due to rainfall, a broken water line, or other reasons. The extra soil moisture tends to speed up sliding soil failures.

The Three Common Factors

Soil failures that cause sliding can occur for any number of reasons. However, three of the most common factors that increase the chances of soil failure from sliding are:

1. excessive vibration,

2. surface encumbrances, and

3. wet conditions.

2. Which of the following is NOT a common factor that increases the chance of soil failure from sliding?

a. Excessive vibration
b. Surface encumbrances
c. Wet conditions
d. Trench dimensions

Soil Instability

A number of stresses and deformations can occur in an open cut or trench causing soil instability and failure.

Moisture

Increases or decreases in soil moisture due to rain or underground seepage can decrease soil cohesion while at the same time increase the weight of the soil. These two factors can adversely affect the stability of a trench or excavation.

Tension Cracks

Tension cracks usually form at a horizontal distance of 0.5 to 0.75 times the depth of the trench, measured from the top of the vertical face of the trench. They may result in sliding or sluffing.

During a visual test, the evaluator should check for crack-line openings along the failure zone that would indicate tension cracks, look for existing utilities that indicate that the soil has previously been disturbed, and observe the open side of the excavation for indications of layered geologic structuring.

3. Tension cracks usually form at a horizontal distance of _____.

a. 1.5 to 3.5 times the height of the trench
b. 0.25 to 0.5 times the length of the trench
c. 0.5 to 0.75 times the depth of the trench
d. 0.75 to 2.5 times the width of the trench

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 that may trap or bury workers in the trench.

4. What may occur when the trench's vertical face shears along the tension crack line?

a. Subsidence
b. Boiling
c. Toppling
d. Bottom heaving

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.

5. Which of the choices below is caused by a high-water table?

a. Heaving or Squeezing
b. Boiling
c. Soil flaking
d. Up-dwelling

Real-World Accident

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.

6. What must be provided in trenches 4 or more feet deep?

a. Sloping
b. Ladders
c. Shoring
d. Trench boxes

Module 4: Methods of Protection

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.

OSHA standard 1926.652, Requirements for protective systems, details four 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 such as spoil and other materials used in the trench, and other nearby operations such as heavy equipment and vehicle traffic.

Requirements

1926.652(a) Protection of employees in excavations.

(1) Each employee in an excavation shall be protected from cave-ins by an adequate protective system designed in accordance with paragraph (b) or (c) of this section except when:

(i)Excavations are made entirely in stable rock; or

(ii)Excavations are less than 5 feet (1.52m) in depth and examination of the ground by a competent person provides no indication of a potential cave-in.

(2) Protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied or transmitted to the system.

See Requirements for Protection Systems" for detailed slope configurations.

Appendix B Requirements and Definitions

(a) ***Scope and application***. This appendix contains specifications for sloping and benching when used as methods of protecting employees working in excavations from cave-ins. The requirements of this appendix apply when the design of sloping and benching protective systems is to be performed in accordance with the requirements set forth in 1926.652(b)(2).

(b) ***Definitions.***

Actual slope means the slope to which an excavation face is excavated.

Distress means that the soil is in a condition where a cave-in is imminent or is likely to occur. Distress is evidenced by such phenomena as the development of fissures in the face of or adjacent to an open excavation; the subsidence of the edge of an excavation; the slumping of material from the face or the bulging or heaving of material from the bottom of an excavation; the spalling of material from the face of an excavation; and ravelling, i.e., small amounts of material such as pebbles or little clumps of material suddenly separating from the face of an excavation and trickling or rolling down into the excavation.

Maximum allowable slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Short term exposure means a period of time less than or equal to 24 hours that an excavation is open.

1. Which of the following is considered the safest of the four methods to prevent an excavation wall collapse?

a. Engineered design
b. Timber shoring
c. Sloping/benching
d. Shielding

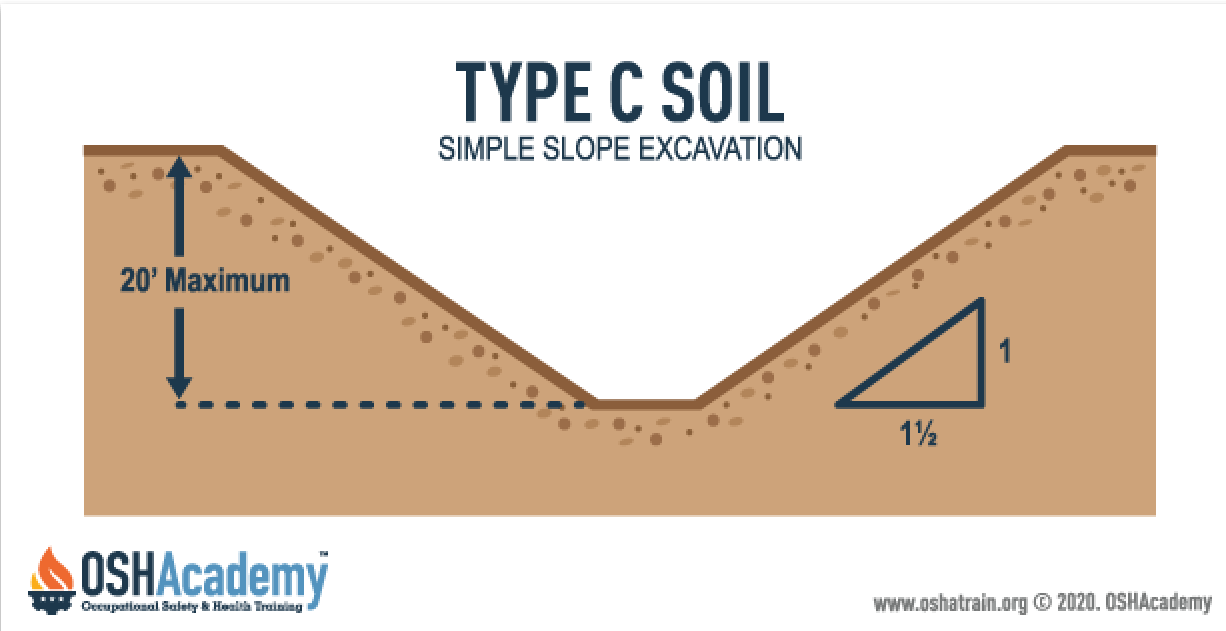
Sloping Systems

As mentioned earlier, sloping is one of the most common protection systems used. It is 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. the safe angle must be more gradual 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 example in the image below shows the sloping requirements for Type C soil. Note the ratio of the slope is 1½:1. For every 1½ feet horizontally, the height of the slope increases by 1 foot. The angle of the slope in this example is 34 degrees. (Click the Appendix B button below to see the Maximum Allowable Slope chart.)



1926.652(b) Design of sloping and benching systems. The slopes and configurations of sloping and benching systems shall be selected and constructed by the employer or his designee and shall be in accordance with the requirements of paragraph (b)(1); or, in the alternative, paragraph (b)(2); or, in the alternative, paragraph (b)(3), or, in the alternative, paragraph (b)(4), as follows:

(1) Option (1)-Allowable configurations and slopes

> (i) Excavations shall be sloped at an angle not steeper than one and one-half horizontal to one vertical (34 degrees measured from the horizontal), unless the employer uses one of the other options listed below.

(ii) Slopes specified in paragraph (b)(1)(i) of this section, shall be excavated to form configurations that are in accordance with the slopes shown for Type C soil in appendix B to this subpart.

(2) Option (2)-Determination of slopes and configurations using Appendices A and B. Maximum allowable slopes, and allowable configurations for sloping and benching systems, shall be determined in accordance with the conditions and requirements set forth in appendices A and B to this subpart.

(3) Option (3)-Designs using other tabulated data.

(i) Designs of sloping or benching systems shall be selected from and be in accordance with tabulated data, such as tables and charts.

(ii) The tabulated data shall be in written form and shall include all of the following:

(A) Identification of the parameters that affect the selection of a sloping or benching system drawn from such data;

(B) Identification of the limits of use of the data, to include the magnitude and configuration of slopes determined to be safe;

(C) Explanatory information as may be necessary to aid the user in making a correct selection of a protective system from the data.

(iii) At least one copy of the tabulated data which identifies the registered professional engineer who approved the data, shall be maintained at the jobsite during construction of the protective system. After that time the data may be stored off the jobsite, but a copy of the data shall be made available to the Secretary upon request.

(4) Option (4)-Design by a registered professional engineer.

(i) Sloping and benching systems not utilizing Option (1) or Option (2) or Option (3) under paragraph (b) of this section shall be approved by a registered professional engineer.

(ii) Designs shall be in written form and shall include at least the following:

(A) The magnitude of the slopes that were determined to be safe for the particular project;

(B)The configurations that were determined to be safe for the particular project; and

(C) The identity of the registered professional engineer approving the design.

(iii) At least one copy of the design shall be maintained at the jobsite while the slope is being constructed. After that time the design need not be at the jobsite, but a copy shall be made available to the Secretary upon request.

1926.652(f) Sloping and benching systems. Employees shall not be permitted to work on the faces of sloped or benched excavations at levels above other employees except when employees at the lower levels are adequately protected from the hazard of falling, rolling, or sliding material or equipment.

Appendix B

(c) ***Requirements.***

(1) ***Soil classification***. Soil and rock deposits shall be classified in accordance with appendix A to subpart P of part 1926.

(2) ***Maximum allowable slope.*** The maximum allowable slope for a soil or rock deposit shall be determined from Table B-1 of this appendix.

(3) ***Actual slope*.**

(i) The actual slope shall not be steeper than the maximum allowable slope.

(ii) The actual slope shall be less steep than the maximum allowable slope, when there are signs of distress. If that situation occurs, the slope shall be cut back to an actual slope which is at least 1/2 horizontal to one vertical (1/2H:1V) less steep than the maximum allowable slope.

(iii) When surcharge loads from stored material or equipment, operating equipment, or traffic are present, a competent person shall determine the degree to which the actual slope must be reduced below the maximum allowable slope and shall assure that such reduction is achieved. Surcharge loads from adjacent structures shall be evaluated in accordance with 1926.651(i).

(4)***Configurations***. Configurations of sloping and benching systems shall be in accordance with Figure B-1.

TABLE B-1
MAXIMUM ALLOWABLE SLOPES

SOIL OR ROCK TYPE	MAXIMUM ALLOWABLE SLOPES (H:V)(1) FOR EXCAVATIONS LESS THAN 20 FEET DEEP(3)
STABLE ROCK TYPE A (2) TYPE B TYPE C	VERTICAL (90°) 3/4:1 (53°) 1:1 (45°) 1 ½:1 (34°)

Footnote(1) Numbers shown in parentheses next to maximum allowable slopes are angles expressed in degrees from the horizontal. Angles have been rounded off.

Footnote(2) A short-term maximum allowable slope of 1/2H:1V (63°) is allowed in excavations in Type A soil that are 12 feet (3.67 m) or less in depth. Short-term maximum allowable slopes for excavations greater than 12 feet (3.67 m) in depth shall be 3/4H:1V (53°).

Footnote(3) Sloping or benching for excavations greater than 20 feet deep shall be designed by a registered professional engineer.

See Appendix B for detailed slope configurations.

2. Type C soil must have a slope no greater than _____.

a. 1:1.5 or 66 °
b. ¾:1 or 53 °
c. 1:1 or 45 °
d. 1½:1 or 34 °

Benching Systems

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.
- In Type B soil, the trench excavation is permitted only in cohesive soil.

Definitions.
Actual slope means the slope to which an excavation face is excavated.

Distress means that the soil is in a condition where a cave-in is imminent or is likely to occur. Distress is evidenced by such phenomena as the development of fissures in the face of or adjacent to an open excavation; the subsidence of the edge of an excavation; the slumping of material from the face or the bulging or heaving of material from the bottom of an excavation; the spalling of material from the face of an excavation; and ravelling, i.e., small amounts of material such as pebbles or little clumps of material suddenly separating from the face of an excavation and trickling or rolling down into the excavation.

Maximum allowable slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Short term exposure means a period of time less than or equal to 24 hours that an excavation is open.

3. As a general rule, the bottom vertical bench height of a multiple-benched trench must not exceed _____.

a. 2 feet
b. 3 feet
c. 4 feet
d. 5 feet

Sloping and Benching 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;
- expose or place utilities (such as electrical power, water, and gas lines) above the angle for a safe slope; and

- cause damage from 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 1/2 feet or less. The collapse of one bench into a lower bench can, in turn, cause a lower bench to fail in a situation where many benches have been created.

Preparing to Slope or Bench

Before the start of sloping or benching, the contractor needs to:

- determine soil types at the excavation site using the soil classification system;
- consider potential sloping and benching problems; and
- identify all protective measures necessary to ensure safe working conditions, and
- determine which protection method is the best to use at the site.

4. What is a common hazard when multiple benches have been created for an excavation?

a. The collapse of one bench into a lower bench
b. Multiple subsidence occurs in Type A soil
c. The slope tends to deform near the top of the trench
d. Entry and exit from the trench is difficult due to benching

Shoring Systems

A shoring system is a structure such as a metal hydraulic, mechanical or timber shoring system that supports the sides of an excavation and which is designed to prevent caveins. Shoring or shielding is used when the location or depth of the cut makes sloping back to the maximum allowable slope impractical.

Timber Shoring. Timber shoring systems are very versatile since they are custom built to fit the trench. Deep and long trenches are probably better suited to timber shoring than any other form of protective system. It is suited well for excavations where significant time is to be spent in one area.

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. 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 any 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. Compressed air is used instead of hydraulic fluid to expand the trench jacks into position.

Screw Jack systems. Screw jack systems differ from hydraulic and pneumatic systems in that the struts of a screw jack system must be adjusted manually. This creates a hazard because the worker is required to be in the trench in order to adjust the strut. In addition, uniform "preloading" cannot be achieved with screw jacks, and their weight creates handling difficulties.

Single-Cylinder Hydraulic Shores. Shores of this type are generally used in a water system, as an assist to timber shoring systems, and in shallow trenches where face stability is required.

Underpinning. This process involves stabilizing adjacent structures, foundations, and other intrusions that may have an impact on the excavation. As the term indicates, underpinning is a procedure in which the foundation is physically reinforced. Underpinning should be conducted only under the direction and with the approval of a registered professional engineer.

See 1926.652(c) requirements, Appendix C

Appendix D Requirements

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.

More requirements for hydraulic shoring.

5. Hydraulic shoring provides a critical safety advantage over timber shoring when installing shoring because _____.

a. the wood tools are not required
b. workers do not have to enter the trench
c. the screw jacks might break the wales
d. workers trust hydraulic jacks more

Shielding Systems

In this method, a trench box or shield designed or approved by a registered professional engineer is used. Timber, aluminum, or other suitable material may be used in the construction. The OSHA standard permits 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.

When installing a trench shield, the contractor should excavate a wider area than the necessary minimum. This provides a more comfortable working environment for your employees in the trench.

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. 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!

1926.652(g) Shield systems-

- (1) General.
  - (i) Shield systems shall not be subjected to loads exceeding those which the system was designed to withstand.
  - (ii) Shields shall be installed in a manner to restrict lateral or other hazardous movement of the shield in the event of the application of sudden lateral loads.
  - (iii) Employees shall be protected from the hazard of cave-ins when entering or exiting the areas protected by shields.
  - (iv) Employees shall not be allowed in shields when shields are being installed, removed, or moved vertically.
- (2) Additional requirement for shield systems used in trench excavations. Excavations of earth material to a level not greater than 2 feet (.61 m) below the bottom of a shield

shall be permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the shield.

See Appendix B for detailed slope configurations.

6. When is a protective system NOT required for an excavation?

a. When the excavation is dug in undisturbed soil
b. When the excavation is dug in Type A or Type B soil
c. When the excavation is dug in loose rock
d. When the excavation is less than five feet deep

Selecting Protective Systems

The following figures are a graphic summary of the requirements contained in subpart P for excavations 20 feet or less in depth. Where the working area of an excavation is constantly moving, as in laying a conduit, shield systems or trench boxes may be the more appropriate protective devices to use.

Protective systems for use in excavations more than 20 feet in depth must be designed by a registered professional engineer in accordance with Sec. 1926.652 (b) and (c).

Click the link to see the selection charts from 1926 Subpart P App F.

7. Protective systems for use in excavations more than 20 feet in depth must be designed by ______.

a. a certified safety professional
b. a qualified person
c. a competent person
d. a registered professional engineer

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.
- An OSHA investigator was performing a worksite inspection on a 10 ft deep trench being dug by ABC Construction. 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.

8. OSHA standards mandate that all excavations _____ be protected against collapse.

a. 4 feet deep
b. 5 feet or deeper
c. more than 6 feet deep
d. of any depth

Module 5: Employer Requirements

Materials and Equipment

The employer is 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 or equipment is not damaged or defective;
- manufactured materials or equipment is used and maintained consistent with the manufacturer's recommendations;
- a competent person examines all damaged materials and equipment; and
- unsafe materials or equipment is removed from service until a registered professional engineer evaluates and approves it for use

1926.652(d) Materials and equipment.

(1) Materials and equipment used for protective systems shall be free from damage or defects that might impair their proper function.

(2) Manufactured materials and equipment used for protective systems shall be used and maintained in a manner that is consistent with the recommendations of the manufacturer, and in a manner that will prevent employee exposure to hazards.

(3) When material or equipment that is used for protective systems is damaged, a competent person shall examine the material or equipment and evaluate its suitability for continued use. If the competent person cannot assure the material or equipment is able to support the intended loads or is otherwise suitable for safe use, then such material or equipment shall be removed from service and shall be evaluated and approved by a registered professional engineer before being returned to service.

See Appendix B for detailed slope configurations.

1. Who must examine all damaged excavation materials and equipment?

a. The project manager
b. A registered engineer
c. A competent person
d. The manufacturer

Installing and Removing Protective Systems

The Excavation standards require employers to take certain steps to protect workers when installing and removing support systems. For example:

- Members of support systems must be securely connected to prevent sliding, falling, kickouts or predictable failure.
- Support systems must be installed and removed in a manner that protects workers from cave-ins and structural collapses and from being struck by members of the support system.
- Members of support systems must not be overloaded.
- Before temporary removal of individual members, additional precautions are required, such as installing other structural members to carry loads imposed on the support system.
- Removal must begin at, and progress from, the bottom of the excavation.
- Members shall be released slowly so as to note any indication of possible failure of the remaining members of the structure or possible cave-in of the sides of the excavation.
- Backfilling must progress together with the removal of support systems from excavations.

The standards permit excavation of 2 feet (0.61 meters) or less below the bottom of the members of a support system, but only if the system is designed to resist the forces calculated for the full depth of the trench and there are no indications, while the trench is open, of a possible loss of soil from behind or below the bottom of the support system. Employers must coordinate the installation of support systems with the excavation work.

2. Removal of excavation protective systems must _____.

a. be removed from the top down
b. occur quickly to protect workers
c. be approved by the site supervisor
d. begin at the bottom of the excavation

Access and Egress

Worker safety may depend on how quickly they can climb out of an excavation. OSHA requires employers to provide ladders, steps, ramps, or other safe means of egress for workers working in trench excavations 4 feet (1.22 meters) or deeper.

- The means of egress must be located so as not to require workers to travel more than 25 feet (7.62 meters) laterally within the trench.
- Structural ramps used by workers to enter and exit the site must have non-slip surfaces and be designed by a competent person.
- Structural ramps used for access or egress of equipment must be designed by a competent person qualified in structural design.
- Structural members used for ramps or runways must be uniform in thickness and joined in a manner to prevent tripping or displacement.
- A competent person must also evaluate ramps made from soil that are used to enter and exit an excavation.

3. The means of egress in a trench must be located within _____ laterally.

a. 15 feet
b. 25 feet
c. 30 feet
d. 35 feet

Water Accumulation

The employer must prohibit employees from working in excavations where water has accumulated or is accumulating without adequate protection.

- If water enters the excavation through the soil for any reason, the soil must be considered Type C and adequate protection must be provided.
- 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.
- If workers enter excavations, methods for controlling standing water and water accumulation must be provided and meet the following requirements:
  - use of special support or shield systems is approved by a registered professional engineer;
  - water removal equipment, i.e., well pointing, is used and monitored by a competent person;
  - safety harnesses and lifelines are used;
  - surface water is diverted away from the trench;
  - employees are removed from the trench during rainstorms; and
  - trenches are carefully inspected by a competent person after each rain and before employees are permitted to re-enter the trench.

OSHA standards also require the employer to use 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.

4. If water enters the excavation through the soil for any reason, the soil must be considered _____.

a. Type A
b. Type B
c. Type C
d. Type D

Fall Protection

Employers must ensure that any worker who enters a bell- bottom pier hole or similar deep and confined footing excavation wears a harness with a lifeline. The lifeline must be attached securely to the harness and must be separate from any line used to handle materials. Also, the lifeline must be individually attended by an observer at all times when the worker wearing the lifeline is in the excavation.

Falling Loads and Moving Equipment

In addition to cave-ins and related hazards, workers involved in excavation work are exposed to hazards involving falling loads and mobile equipment. To protect workers from these hazards, OSHA requires employers to take certain precautions. For example, employers must:

- Place spoils, (see example) stored materials, and equipment at least 2 feet (0.61 meters) from the edge and/or by using a retaining device to keep the materials or equipment from falling or rolling into the excavation.
- Provide a warning system (such as barricades, spotters using hand or mechanical signals.
- Use stop blocks when mobile equipment must approach the edge of an excavation and the operator does not have a clear and direct view of the edge.
- Protect workers from loose rock or soil that could fall or roll from an excavation face by scaling to remove loose material, installing protective barricades at appropriate intervals, or using other equivalent forms of protection.
- Institute and enforce work rules prohibiting workers from working on faces of sloped or benched excavations at levels above other workers unless the workers at the lower levels are adequately protected from the hazards of falling, rolling, or sliding material or equipment.
- Institute and enforce work rules prohibiting workers from standing or working under loads being handled by lifting or digging equipment.
- Require workers to stand away from vehicles being loaded or unloaded to protect them from being struck by any spillage or falling materials. (Operators may remain inside the cab of a vehicle being loaded or unloaded if the vehicle is equipped, in accord with 29 CFR 1926.601(b)(6), to provide adequate protection for the operator.)

1926.652(e) Installation and removal of support-

(1) General.

- (i) Members of support systems shall be securely connected together to prevent sliding, falling, kickouts, or other predictable failure.

- (ii) Support systems shall be installed and removed in a manner that protects employees from cave-ins, structural collapses, or from being struck by members of the support system.
- (iii) Individual members of support systems shall not be subjected to loads exceeding those which those members were designed to withstand.
- (iv) Before temporary removal of individual members begins, additional precautions shall be taken to ensure the safety of employees, such as installing other structural members to carry the loads imposed on the support system.
- (v) Removal shall begin at, and progress from, the bottom of the excavation. Members shall be released slowly so as to note any indication of possible failure of the remaining members of the structure or possible cave-in of the sides of the excavation.
- (vi) Backfilling shall progress together with the removal of support systems from excavations.

1926.652(e)(2) Additional requirements for support systems for trench excavations.

- (i) Excavation of material to a level no greater than 2 feet (.61 m) below the bottom of the members of a support system shall be permitted, but only if the system is designed to resist the forces calculated for the full depth of the trench, and there are no indications while the trench is open of a possible loss of soil from behind or below the bottom of the support system.
- (ii) Installation of a support system shall be closely coordinated with the excavation of trenches.

Appendix B

(c) ***Requirements.***

(1) ***Soil classification***. Soil and rock deposits shall be classified in accordance with appendix A to subpart P of part 1926.

(2) ***Maximum allowable slope.*** The maximum allowable slope for a soil or rock deposit shall be determined from Table B-1 of this appendix.

(3) ***Actual slope*.**

(i) The actual slope shall not be steeper than the maximum allowable slope.

(ii) The actual slope shall be less steep than the maximum allowable slope, when there are signs of distress. If that situation occurs, the slope shall be cut back to an actual slope which is at least ½ horizontal to one vertical (½H:1V) less steep than the maximum allowable slope.

(iii) When surcharge loads from stored material or equipment, operating equipment, or traffic are present, a competent person shall determine the degree to which the actual slope must be reduced below the maximum allowable slope, and shall assure that such reduction is achieved. Surcharge loads from adjacent structures shall be evaluated in accordance with 1926.651(i).

(4)***Configurations***. Configurations of sloping and benching systems shall be in accordance with Figure B-1.

TABLE B-1
MAXIMUM ALLOWABLE SLOPES

SOIL OR ROCK TYPE	MAXIMUM ALLOWABLE SLOPES (H:V)(1) FOR EXCAVATIONS LESS THAN 20 FEET DEEP(3)
STABLE ROCK TYPE A (2) TYPE B TYPE C	VERTICAL (90º) 3/4:1 (53º) 1:1 (45º) 1 ½:1 (34º)

Footnote(1) Numbers shown in parentheses next to maximum allowable slopes are angles expressed in degrees from the horizontal. Angles have been rounded off.

Footnote(2) A short-term maximum allowable slope of 1/2H:1V (63º) is allowed in excavations in Type A soil that are 12 feet (3.67 m) or less in depth. Short-term maximum allowable slopes for excavations greater than 12 feet (3.67 m) in depth shall be 3/4H:1V (53º).

Footnote(3) Sloping or benching for excavations greater than 20 feet deep shall be designed by a registered professional engineer.

See Appendix B for detailed slope configurations.

5. What is the excavation requirement for spoils, materials, and equipment?

a. Locate them at either end of the trench
b. Place a barrier between them and the trench
c. Get approval for their placement away from the trench
d. Place them at least two feet from the trench

Excavation Training

Cooperation between employers and employees is necessary to make sure excavation safety training policies are developed and implemented effectively. Each project supervisor and competent person must understand their responsibility for providing effective safety training to ensure a safe working environment. Effective excavation training includes a hands-on practice component to make sure workers have adequate knowledge, skills, and the ability to perform tasks safely (KSAs).

Employee excavation training should include the following topic 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, architectural, and archeological artifacts.

6. Which component of excavation training helps to determine workers have adequate knowledge, skills, and abilities (KSAs) to complete tasks safely?

a. Attendance sheet signed by the supervisor
b. The OSHA 10-hour training module
c. At least one hour of classroom training
d. A hands-on practice component prior to work

Adjacent Structures

The Excavation standards require employers to provide support systems, such as shoring, bracing, or underpinning, when necessary to ensure that adjacent structures (including adjoining buildings, walls, sidewalks and pavements) remain stable for the protection of workers. The standards also prohibit excavation below the base or footing of any foundation or retaining wall that could be reasonably expected to pose a hazard to workers unless:

- The employer provides a support system, such as underpinning;
- The excavation is in stable rock; or
- A registered professional engineer determines that the structure is far enough away from the excavation that it would not be affected by the excavation activity or that the excavation work will not pose a hazard to workers.

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.

7. In which situation would an excavation next to a foundation or retaining wall be initially prohibited?

a. The excavation is in stable rock
b. The excavation is approved by a registered professional engineer
c. The foundation or retaining wall creates a hazard
d. The employer has provided suitable underpinning

Residential Construction

OSHA recognizes that residential construction sites can be very different from commercial sites as they relate to excavations. In 1995, OSHA suspended the requirements of 1926.652 to house foundation/basement excavations. (OSHA Letter of Interpretation 1995-06-30).

The exemption applies only if ALL six of the following conditions are present:

1. the house foundation/basement excavation is less than 7½ feet in depth or is benched for at least 2 feet horizontally for every 5 feet or less of vertical height;

2. the minimum horizontal width at the bottom of the excavation is as wide as needed, but not less than 2 feet;

3. there is no water, surface tension cracks or other environmental conditions present that reduce the excavation stability;

4. there is no heavy equipment operating in the vicinity that causes vibration to the excavation while employees are in the excavation;

5. work crews in the excavation are the minimum number needed to perform the work; and

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

However, it's important to note that OSHA 1910.652 does still apply if any of the above conditions are not met.

This policy applies to all house foundation/basement excavations including those which become trenches by definition when formwork, foundations, or walls are constructed. This policy does not apply to utility excavations (trenches) where 29 CFR 1926.652 remains applicable.

8. Which of the following is TRUE regarding the residential basement/foundation exemption for excavations?

a. The exemption applies to all utility excavations
b. In 1995, OSHA reinstated the residential construction requirement
c. One of the six exemption conditions must be present
d. All six exemption conditions must be present

On-site Inspection

The employer must ensure documented inspections are conducted by a competent person. The following guide specifies the frequency and conditions requiring inspections:

- Daily and before the start of each shift;
- As dictated by the work being done in the trench;
- After every rainstorm;
- After other events that could increase hazards, e.g. snowstorm, windstorm, thaw, earthquake, etc.;
- When fissures, tension cracks, sloughing, undercutting, water seepage, bulging at the bottom, or other similar conditions occur;
- When there is a change in the size, location, or placement of the spoil pile; and
- When there is any indication of change or movement in adjacent structures.

If the inspector finds any unsafe conditions during an inspection, they must clear employees from the hazardous area until safety precautions are in place.

See a sample Excavation Safety Checklist that can help conduct inspections.

9. What must the inspector do if unsafe conditions in a trench are discovered during an inspection?

a. Note the condition on the inspection checklist
b. Immediately clear workers until the trench is safe
c. Ask for an OSHA consultation about the hazard
d. Hire a registered engineer to recommend a fix

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.

1. The contractor must always contact the utility companies involved and inform them of the work _____.

a. to let them know work has been completed
b. if an emergency occurs during normal work hours
c. before starting the trench or excavation
d. when suggested by the project safety manager

Access and Egress

A stairway, ladder, ramp or other safe means of access and egress must be located in trench excavations that are 4 feet (1.22 m) or more in depth so as to require no more than 25 feet (7.62 m) of lateral travel for employees.

Structural Ramps and Runways

- Structural ramps that are used solely by employees as a means of access or egress from excavations must be designed by a competent person.
- Structural ramps used for access or egress of equipment must be designed by a competent person qualified in structural design and must be constructed in accordance with the design.
- Ramps and runways constructed of two or more structural members must have the structural members connected together to prevent displacement.

Structural Members for Ramps and Runways

- Structural members used for ramps and runways must be of uniform thickness.
- Cleats or other appropriate means used to connect runway structural members must be attached to the bottom of the runway or must be attached in a manner to prevent tripping.
- Structural ramps used in lieu of steps must be provided with cleats or other surface treatments on the top surface to prevent slipping.

2. Structural ramps that are used solely by employees for access or egress from excavations _____.

a. may be designed by employees working in the excavation
b. are not allowed in Type B or C soil
c. are not required for excavations less than 10 feet in depth
d. must be designed by a competent person

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

3. Each of the following is a requirement for trench walkways or bridges EXCEPT _____.

a. they must be fitted with standard rails
b. they must be made with reinforced metal plates
c. they must have a minimum width of 20 inches
d. they must extend at least 24 inches past the surface edge

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

Warning Systems for Mobile Equipment

The following steps should be taken to prevent vehicles from accidentally falling into the trench:

- Barricades must be installed where necessary.
- Hand or mechanical signals must be used as required.
- Stop logs must be installed if there is a danger of vehicles falling into the trench.

- Soil should be graded away from the excavation; this will assist in vehicle control and channeling of run-off water.

4. Which of the following practices is NOT allowed while working in a trench?

a. Work in a sloped trench with Type C soil
b. Working under a raised load
c. Entering an unguarded 4 ft deep trench without shoring
d. Working in a trench without a coworker

Underground Utilities

There are important steps the employer should take to minimize the risk of unexpectedly encountering underground utilities such as sewer, telephone, fuel, electric, water lines, or any other underground installations that reasonably may be expected to be encountered during excavation work. Before starting work, the Excavation standards require employers to do the following:

- Determine the approximate location(s) of utility installations. One common industry practice is to call 811, the "Call Before You Dig" number, to establish the location of any underground utility installations in the work area.
- Contact and notify the utility companies or owners involved at least 2 days prior to the start of work to inform them of the proposed work.
- Ask utility companies or owners to establish the location of underground installations prior to the start of excavation work. If they cannot respond within 24 hours (unless the period required by state or local law is longer) or cannot establish the exact location of the utility installations, employers may proceed with caution, which includes using detection equipment or other acceptable means to locate utility installations.
- Determine the exact location of underground installations by safe and acceptable means when excavation operations approach the approximate location of the installations.
- Ensure that while the excavation is open, underground installations are protected, supported or removed as necessary to safeguard workers.

5. If a utility company cannot establish the exact location of an underground utility, what action may the employer take?

a. Proceed with caution using an acceptable means of detection
b. Close down the project until the utility company arrives
c. Continue the excavation using experience and common sense
d. Get permission from OSHA to continue with the project

Hazardous Atmospheres In Excavations

Common hazardous atmospheres might be due to methane, hydrogen sulfide, and carbon monoxide. Precautions include providing workers with proper respiratory protection or forced air ventilation. Do not assume that natural ventilation (natural air movement across and into the excavation) is sufficient to keep an atmosphere safe in the trench.

Employees must not work in hazardous and/or toxic atmospheres including those with:

- Less than 19.5% or more than 23.5% oxygen;
- A combustible gas concentration greater than 20% of the lower flammable limit; and
- Concentrations of hazardous substances that exceed those specified in the Threshold Limit Values for Airborne Contaminants established by the ACGIH (American Conference of Governmental Industrial Hygienists).

All operations involving hazardous atmospheres must be conducted in accordance with OSHA requirements for occupational health and environmental controls (see 29 CFR Part 1926 Subpart D) for personal protective equipment and for lifesaving equipment (see 29 CFR Part 1926 Subpart E). Engineering controls (e.g., ventilation) and respiratory protection may be required.

A competent person must test an excavation before employees enter an excavation greater than 4 feet (1.22 m) in depth for where hazardous atmospheres exist or could reasonably be expected to exist, such as in excavations in landfill areas or excavations in areas where hazardous substances are stored nearby.

When testing for atmospheric contaminants within excavations or confined spaces in excavations, the following should be considered:

- Testing should be conducted before employees enter the trench and should be done regularly to ensure that the trench remains safe.

- The frequency of testing should be increased if equipment is operating in the trench.
- Testing frequency should also be increased if welding, cutting, or burning is done in the trench.

6. What is a primary control measure if a flammable/combustible atmosphere is detected in a trench?

a. Water suppression system
b. Forced air ventilation
c. Natural ventilation
d. Reduced work

Hazardous Atmospheres In Confined Spaces

29 CFR Part 1926, Subpart AA applies to non-excavation work within a confined space located in an excavation. These standards are intended to complement the excavation standard and address two distinct hazards:

1. hazardous atmospheres in excavations and
2. the additional hazards associated with confined spaces located within excavations.

For example, the Confined Spaces in Construction standard covers entry into a large prefabricated storm drain, other pipe, or manhole large enough for human occupation, even if located at the bottom of an open excavation.

If unhealthful atmospheric conditions exist or develop in an excavation or confined space, workers must exit immediately, and not reenter until testing proves safe levels have been achieved. Under no circumstance may workers enter an excavation when flammable/combustible atmospheres are present.

Emergency Rescue

Emergency rescue equipment is required when a hazardous atmosphere exists or can reasonably be expected to exist. Requirements are as follows:

- Respirators must be of the type suitable for the exposure. Employees must be trained in their use and a respirator program must be instituted.
- Attended (at all times) lifelines must be provided when employees enter bell-bottom pier holes, deep confined spaces, or other similar hazards.

- Employees who enter confined spaces must be trained.

7. Which of the following is an example of a non-excavation confined space within an excavation?

a. A 2 ft wide pipe for electrical wiring
b. An area protected with a trench box
c. A large storm drain
d. A 10 ft excavation

Real-Life Scenario

Two employees were installing storm drainpipes 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.

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)).

8. A trench is 12 feet deep and 5 feet wide. The unprotected walls consist of unstable soil with beginning to seep into the trench. You are the competent person. What are your actions?

a. Confer with the contractor for instructions
b. Order timber shoring for the trench
c. Tell the workers to monitor the seeping water
d. Tell the workers to exit the trench

